88-e24

Segment No. 01-01-99

WA-01-3110

INVESTIGATION OF RECURRENT COHO SALMON MORTALITY AT THE MARITIME HERITAGE FISH HATCHERY IN BELLINGHAM, WASHINGTON

by
Will Kendra

Washington State Department of Ecology
Water Quality Investigations Section
Olympia, Washington 98504-6811

June 1988

ABSTRACT

In 1987, the Washington State Department of Ecology investigated recurrent coho salmon kills at Maritime Heritage Fish Hatchery. Hatchery water is drawn from the mouth of Whatcom Creek, which drains Lake Whatcom and downtown Bellingham. Mortality occurs after the first or second rain event of the wet season and thus may be linked to the "first flush" of pollutants into the creek. Stream sampling demonstrated that: (1) water quality degradation arose chiefly from urban stormwater runoff; (2) federal toxicity criteria for several metals and pentachlorophenol were exceeded in Whatcom and/or Fever Creeks; (3) sediments were also contaminated with heavy metals and pentachlorophenol; and (4) invertebrate communities were largely unaffected by stream pollution. Hatchery sampling during or shortly after two kill events failed to elucidate the causative agent(s). Heavy metal toxicity from multiple sources is strongly suspected, though pentachlorophenol may also play a role. Recommendations include resampling of hatchery water during the next kill and investigating the origin of fecal, metal, and pentachlorophenol contamination in Whatcom Creek.

INTRODUCTION

Maritime Heritage Fish Hatchery (MHFH) is located in downtown Bellingham near the mouth of Whatcom Creek (Figure 1). The hatchery is a cooperative venture of the Bellingham Vocational Technical Institute and the city of Bellingham. Several species of anadromous salmonids are reared: coho, chinook, and chum salmon (*Oncorhynchus kisutch*, *O. tshawytscha*, and *O. keta*); steelhead trout (*Salmo gairdneri*); and sea-run cutthroat trout (*S. clarki*).

The hatchery draws its water from river mile (RM) 0.2 of Whatcom Creek, just upstream of a waterfall and the zone of tidal influence. The screened intake is located under the Dupont Street bridge near the right bank (facing downstream). Withdrawn water initially enters a settling pond, then flows separately through two rearing ponds before discharging to the creek mouth.

MHFH is plagued by recurrent kills of coho salmon every autumn. Other species reared at the facility appear unaffected. The kills are typically associated with the first or second major rain event of the wet season. However, in 1987 a coho kill also occurred in spring after heavy rainfall succeeded a prolonged dry spell.

The recurrent mortality affects both juvenile and adult coho salmon. Hatchery losses usually total 1 percent, but have exceeded 10 percent. Coho kills occur simultaneously in Whatcom Creek.

Affected fish spiral and gasp at the surface prior to death. Postmortem examinations reveal ruptured gill filaments. Investigations by fish pathologists have ruled out disease and diet as possible causes. The nature of mortality and close association with the "first-flush" of pollutants into Whatcom Creek implicates a toxicant in the water supply.

Whatcom Creek begins at the outlet of Lake Whatcom (Figure 1). Lake overflow is regulated by a manually operated spillway. The stream flows 3.8 miles before entering Bellingham Bay.

Whatcom Creek has three major tributaries: Cemetery Creek (RM 1.75), Fever Creek (RM 1.45), and Lincoln Creek (RM 1.4). The latter two are largely confined to storm sewers and drainage ditches. A fourth tributary, Park Creek (RM 2.8), could not be located and was presumed to be intermittent.

Land use along Whatcom Creek is varied. From the lake outlet to RM 2.2 (Woburn St), the stream winds through steep forested terrain within Whatcom Falls Park. From RM 2.2 to 1.2 (Interstate 5), the stream corridor is undeveloped, but nearby property features residential, commercial, and light industrial use. Below RM 1.2, the stream flows through mixed residential-commercial districts within downtown Bellingham.

A single wastewater discharge to the creek is permitted by Ecology under the National Pollutant Discharge Elimination System (NPDES). The discharge consists of two outfalls from a Washington Department of Wildlife (WDW) fish hatchery located at RM 3.2. Water for this facility is obtained directly from Lake Whatcom.

The only major industry in the watershed is Brooks Lumber Company which borders Fever Creek. Brooks uses a solution of oil and pentachlorophenol (PCP) to preserve wood. Spills of this mixture have contaminated Fever and Whatcom Creeks in the recent past. Most infamous was the January 1981 spill which killed 45,000 salmon and trout worth $116,000 (Kittle 1981). The bulk of the mortality occurred at MHFH. Since that time, Brooks has removed tainted on-site soils and installed a closed (recirculating) wood-treating system.

Whatcom Creek is designated a Class A (Excellent) water body in Chapter 173-201 of the Washington Administrative Code (WAC). Beneficial uses include water supply, fish and wildlife habitat, and recreation. Use-impairment arises from nonpoint pollution, chiefly urban stormwater runoff. Potential contaminants include solids, nutrients, bacteria, oxygen-demanding substances, inorganic toxicants like metals, and organic toxicants like pesticides and petroleum hydrocarbons.

The Northwest Regional Office (NWRO) of Ecology asked the Water Quality Investigations Section (WQIS) to determine the nature and source of the toxicant(s) responsible for the recurrent mortality of coho salmon at MHFH. An investigation was designed with the following elements:

- A literature review of the selective action of toxicants on coho.

- A streamwalk to inventory potential sources of contamination.

- Water quality surveys during both dry and wet seasons.

- Toxicant scans of streambed sediments.

- An assessment of macroinvertebrate community structure.

- Conventional and toxics analyses of hatchery water from a kill event.

Several individuals assisted with field operations and their contribution is acknowledged: Joe Joy of WQIS, Lori LeVander and John Glynn of NWRO, Earl Steele of MHFH, Evan Hornig of the U.S. Environmental Protection Agency (EPA), and Joanne Schuett-Hames of the Lummi Tribal Fisheries Program. EPA provided the sediment toxicant scans through the Washington Sediment Watch program.

METHODS

Intensive water quality surveys of Whatcom Creek were conducted on July 14 and 15 and December 8 and 9, 1987. A total of six mainstem sites, three tributaries, and 14 pipes were sampled (Figure 1). Water samples were also collected by Earl Steele at MHFH during and after the coho kills of May and November 1987. Specific sampling locations and parameters are detailed in Appendix A. Several replicate samples were collected to assess field and laboratory variability.

Field techniques were: discharge by top-setting rod and Swoffer meter, bucket and stopwatch, or eye (estimate); temperature by mercury thermometer; pH and specific conductance by Beckman meter; and dissolved oxygen by azide-modified Winkler titration. The pH meter was periodically recalibrated to ensure accuracy.

Water samples were collected from mid-channel, below the surface where possible. Samples were iced and shipped by bus within 24 hours to the EPA/Ecology laboratory in Manchester, Washington. Sample containers, processing, and analysis conformed to EPA (1983), APHA *et al.* (1985), and Huntamer (1986).

Streambed sediments were collected for toxicant scans at four mainstem sites on July 16, 1987. Sampling stations and parameters are listed in Appendix A. Each sample was a composite of two to four casts of an Emery pipe dredge. Casts were made in depositional (pool) areas. The dredge appeared to sample the upper four inches of sediment.

All sediment sampling and homogenization equipment was stainless steel and pre-cleaned using (in order): Liqui-Nox detergent, de-ionized water, 10 percent nitric acid, de-ionized water, methylene chloride, and acetone. The dredge was rinsed with stream water between sites.

Sediment samples were placed in priority pollutant-cleaned glass jars with teflon-lined lids (ICHEM). Samples were iced and transported within 24 hours to the Manchester laboratory. Toxicant scans followed methods specified in Huntamer (1986); data were not corrected for spike recovery. Grain size and percent solids were measured by

Parametrix, Inc. (Bellevue, WA) using the procedure of Holme and McIntyre (1971). Total organic carbon (TOC) was measured by Lauck's Testing Laboratories, Inc. (Seattle, WA) using the method of Tetra Tech, Inc. (1986).

Aquatic macroinvertebrates were collected from Whatcom Creek during both dry and wet seasons. Sampling sites and dates are noted in Appendix A. Collection methods were as follows:

Summer - Riffle biota were washed from five hand-sized rocks into a 320-um hand net; vegetation biota were sampled by sweeping the hand net through nearshore submerged grasses for 20 to 30 seconds.

Winter - Riffle biota were dislodged into a 920-um hand net by kicking the substrate for 20 to 30 seconds; vegetation biota were sampled as in July except that a 920-um hand net was used.

After collection, each sample was placed in water in a shallow pan. Live organisms were picked without bias at streamside over 5 to 10 minutes and preserved in 70 percent ethanol. Categorical abundance of unpicked organisms was estimated by eye. Invertebrates were later identified to family using the keys of Merritt and Cummins (1978) and Pennak (1978).

A qualitative assessment of habitat condition was made at several mainstem sites (Appendix A) to facilitate interpretation of invertebrate distribution patterns. Habitat characteristics included stream width and depth, substrate and aquatic plant composition, bank stability and vegetation, canopy cover, and adjacent land use.

Weather during the July survey was warm and dry. As expected, the November coho kill followed the first heavy rainstorm of autumn. Survey conditions thereafter were: overcast on November 24; light rainfall on December 7 and 8; and steady rainfall on December 9.

RESULTS AND DISCUSSION

Literature Review

Dead coho at MHFH evidenced considerable gill damage. A variety of aquatic pollutants cause fish gill structural damage, including extremes of temperature and pH, dissolved gases, nitrogenous compounds, detergents, insecticides, herbicides, organic solvents, petroleum compounds, and heavy metals (Eller 1975; Evans 1987).

Mallatt (1985) compiled published accounts of gill pathologies and found that similar lesions appeared under a wide range of irritant-exposure conditions. He concluded that irritant-induced gill damage was largely nonspecific (i.e., a generalized response to stress). Thus the occurrence of ruptured gill filaments in coho salmon at MHFH provided no clue to potential causative agents.

Consequently, the literature was further reviewed with emphasis on the species-specific nature of the kill events. Comparison of the relative toxicity of different compounds to the several species reared at MHFH was confounded by variable bioassay test conditions (e.g., water chemistry, fish age, etc.). To circumvent this bias, the literature search was limited to bioassays which paired coho salmon and one or more of the other species under similar test environments.

Paired bioassay results are shown in Appendix B. Acute toxicity was reported as a 96-hour LC_{50} value (i.e., the toxicant concentration at which 50 percent of the exposed organisms die within 96 hours). LC_{50} confidence intervals were compared to assess relative toxicity, with overlap indicating equal sensitivity/tolerance.

Confidence interval comparisons are summarized in Table 1. In general, coho were equally sensitive or more tolerant to contaminants than chinook salmon and steelhead (=rainbow) trout. No class of compounds tested was more toxic to coho; specific chemicals which were more toxic include the herbicide 2,4,5-T and the insecticides chlordane, DDT, d-trans allethrin, altosid, and SD-16898.

PCP and heavy metals were initially considered prime suspects in the recurrent coho kills, but comparisons of LC_{50} data challenge this hypothesis. Coho and rainbow trout were judged equally sensitive to PCP. Metals comparisons were less clear (see footnote, Appendix B), but coho appeared equally or more tolerant than steelhead to copper and zinc exposure.

Water Quality - Conventionals

The lower two miles of Whatcom Creek were walked on July 15 to identify potential pollutant sources. A partial list was compiled (Appendix C); other sources may have been obscured by dense streamside vegetation. The surveyed reach was typical of urban streams in that litter and stormwater drains were commonplace.

Water quality data from summer and winter sampling runs are presented in Appendix D. Principal components analysis (PCA) was used to reduce the complexity of the data set and reveal its more salient features. A description of this multivariate statistical method is provided in Appendix E.

Two PCA's were performed, one each for summer and winter. Results are graphically displayed in Figure 2. The relative position of sampling sites on a given graph indicates similarity--points (sites) close together are more similar than those far apart. The outward-radiating lines show the variables responsible for site separation (e.g., in summer the pipe at RM 3.22 had relatively high ammonia and phosphorus). Each PCA is interpreted separately below.

Summer

The graphical display accounts for 70 percent of the variation between sampling sites. In general, movement from left to right represents a gradient of increasing contamination.

Mainstem sites (circles) clumped together, with lake outlet water having the highest quality (○ 3.8). Replicate samples (R) showed good agreement (similarity). Day-to-day variability was probably a function of sampling time.

The screen-house overflow (■3.21) and upper WDW hatchery outlet (■3.23) were of similar quality to upper mainstem sites. The lower WDW hatchery outlet (■3.22) had high nutrient levels, likely from food and fecal wastes (most fish in the facility were reared in this flow stream). All three discharges at RM 3.2 originate in Lake Whatcom; together they account for observed increases in flow and nutrient loads between mainstem sites 3.8 and 2.2 (Appendix D).

Cemetery Creek (▲1.75), Lincoln Creek (▲1.4), and the Valencia Street storm drain (■2.1) were of relatively poor quality, but all had negligible flow (lower Fever Creek was not flowing in summer). The Valencia outfall includes water diverted from upper Fever Creek where land use is residential. In April 1987 a canoeist on Whatcom Creek reported eye and respiratory irritation after passing the Valencia Street drain.

Storm drain effluents at Ellis and State Streets (RM 0.8 and 0.75, respectively) were of very poor quality. These discharges were omitted from the PCA because they were statistical outliers. Both had very high turbidity, chemical oxygen demand (COD), nutrients, and fecal coliform (Appendix D), indicating contamination with raw sewage. Bacterial levels in Whatcom Creek were low upstream of these outfalls, but levels downstream exceeded the state water quality standard of 100 organisms per 100 mL (WAC 173-201). Fecal pollution in the Ellis Street outfall had been reported as early as 1980 (Drotts, unpublished manuscript). NWRO should notify the city of Bellingham of the possibility of illegal sewage hook-ups in both storm sewers.

Winter

The winter PCA plot explains 56 percent of the variation among sampling sites. Again, movement from left to right represents a gradient of decreasing water quality. A second gradient, from bottom to top, is one of increasing conductivity and (to a lesser extent) nutrients.

Mainstem sites sampled on December 8 (○) clustered together, with the replicate sample (R) at mile 0.2 showing high precision. A follow-up sample the next day (● 0.2) evidenced considerable degradation; water quality resembled that of storm sewers. The decline in quality is attributed to steady rainfall and consequent runoff, which tripled streamflow between the two sampling periods (Appendix D).

The rainstorm similarly boosted tributary flows, with variable effect on water quality. Fever Creek (△ + ▲ 1.45) appeared more dilute on December 9, with conductivity, COD, and nutrients being lower than the previous day. However, turbidity and fecal coliform remained constant or increased. Fever Creek carried a surface oil sheen on December 9, more so in the afternoon than morning. The aesthetic quality of this tributary was poor.

Flow in Lincoln Creek also increased from December 8 to 9, as did turbidity and fecal coliform (△+▲1.4). Cemetery Creek had relatively good water quality, except for high nitrate-nitrite levels (△1.75).

Like tributaries, pipe effluents were generally characterized by elevated turbidity, COD, nutrients, and fecal coliform. Both tributary and pipe waste loads contributed to repeated violation of the state fecal coliform standard in the lower mainstem.

All of the major storm drains identified in Appendix C were sampled in December. Two that differed from the rest were at Ellis (■ 0.8) and State (■ 0.75) Streets. These same sites were identified as outliers and excluded from the summer PCA analysis. Again, both may stand apart from other inflows due to raw sewage inputs.

In summary, the two PCA analyses showed that: (1) replicate samples had high precision; (2) the quality of inflowing tributaries and pipes was poor; and (3) during major rain events, water quality in Whatcom Creek is not unlike the quality of storm sewer effluent.

Water Quality - Metals

Heavy metals were sampled often because they are by far the most prevalent priority pollutant constituent of urban runoff (Cole *et al.* 1984). Results of metal sampling are shown in Table 2. Values exceeding EPA acute (A) or chronic (C) toxicity criteria are labeled accordingly. The criteria are acid-soluble measures, thus they may be overly protective when compared to total (reported herein) or total recoverable measures.

Metals concentrations in summer were fairly low, except for lead. Pollutant sources are unclear because only mainstem sites were sampled. Lead exceeded the chronic EPA criterion in lake overflow, so natural background levels may be elevated. However, lead concentrations continued to increase farther downstream, peaking at RM 0.7, where the acute toxicity threshold was attained. Thus lead loading in summer may stem from both natural and human influences. Further study of lead pollution in the watershed is warranted.

Copper was the primary metal contaminant in Whatcom Creek in winter. On December 8, the acute toxicity criterion was violated at all four mainstem sites sampled. Levels were constant from site to site, indicating an upstream origin (i.e., above RM 1.8). The only likely discharge between RM 1.8 and Lake Whatcom was the Valencia Street storm drain, but a sample collected there on December 9 had negligible copper. The source of copper contamination above RM 1.8 should be investigated through additional field work.

Earlier LC_{50} comparisons (Table 1; Appendix B) provided scant data on interspecies metal toxicity. Coho salmon and steelhead trout appeared equally sensitive to copper and zinc after correcting for differences in hardness using the method of Brown (1968). However, the validity of such correction is questionable. Mance (1987) reviewed data from (unpaired) toxicity tests and reported that coho and chinook salmon appeared more sensitive to copper exposure than rainbow (=steelhead) trout and other salmonids. Clearly, the database on interspecies metal toxicity is too limited to draw firm conclusions.

Mainstem metals sampling on December 9 was restricted to RM 0.2, where chronic toxicity criteria were exceeded for copper, lead, and zinc (Table 2). The pollutant source appeared to be cumulative inputs from tributaries and storm sewer outfalls. Each sampled inflow violated acute or chronic limits for at least one of the three metals; pipe discharges at RM 1.1 and 1.2 exceeded acute criteria for all three metals.

Despite instream violations of metals criteria in summer and winter, concentrations remained well below lethal levels for coho salmon (96-hour LC_{50}s). However, toxicity may still occur due to synergism, where the combined effect of several metals may exceed the sum of individual effects. Alabaster and Lloyd (1982) reviewed studies on the toxicity of mixtures of metals to fish. They reported five cases where effects were less than additive (antagonistic), 10 where effects were additive, and 10 where effects were greater than additive (synergistic).

Another potential mode of metal toxicity may be associated with the storm sewer outfall at RM 0.2. Discharge occurs on the right bank and the effluent plume likely remains nearshore due to stream hydraulics. Since the MHFH intake is located along the same bank a short distance downstream, pipe effluent may constitute a large portion of hatchery inflow during rain events. On December 9, discharge from this pipe had copper and lead concentrations above federal toxicity thresholds.

1987 Coho Salmon Kills

Shortly after the spring 1987 coho kill, NWRO staff collected water samples at MHFH for PCP analysis. Results are shown in Table 3 and Appendix F. PCP was detected, with concentrations decreasing over time (values should be considered estimates due to method blank contamination). PCP levels were at least an order of magnitude below federal toxicity criteria and reported LC_{50}s for coho. Still, sampling may have occurred after a more concentrated dose of PCP passed through the hatchery. Also, laboratory recoveries of phenolic compounds have historically been poor (C. Kirchmer, Ecology lab, personal communication), thus the true concentration of PCP present may have been higher.

The herbicide bromacil was incidentally detected during spring sampling, but values were relatively low. Call *et al.* (1983) noted that the concentration of bromacil required to adversely affect fish (50 mg/L) would probably not be encountered in aquatic ecosystems.

In July 1987, water samples from three mainstem sites were tested for PCP and bromacil. Traces of each were found (Table 3; Appendix F). PCP was detected upstream of the Fever Creek confluence, but contamination during sampling cannot be ruled out due to lack of field blank data.

The annual autumn coho kill occurred on November 14, 1987, following the first heavy rainfall of the wet season. A full complement of sample bottles had been left at the hatchery, but due to a miscommunication not all of the bottles were filled during the kill. Consequently, toxicant scans on water samples were limited.

Dissolved oxygen levels were more than adequate (Appendix F). Metals were low, except for copper. Assuming a hardness of 35 mg/L, the chronic toxicity criterion for copper was exceeded, but levels did not approach the LC_{50} value for coho (Table 2). A base-neutral/acid (BNA) scan found only phthalates, which are commonly used as plasticizers. Reported concentrations likely posed no threat to aquatic life (EPA 1980).

Three other priority pollutants were detected in hatchery water after the autumn kill: dicamba, tetrachlorophenol (TCP), and PCP (Appendix F). Dicamba has been one of the most extensively used benzoic acid herbicides in the U.S. Lorz *et al.* (1979) determined that coho salmon were unaffected by dicamba concentrations up to 100 mg/L. PCP concentrations were also well below toxic levels (Table 3). TCP, an impurity of PCP, was similarly present in low quantities.

The same three compounds were found during follow-up sampling in Whatcom Creek in December (Appendix F). All increased between RM 1.8 and 1.1. Dicamba was not detected in Fever Creek (RM 1.45), but the chlorinated phenols were. Mainstem PCP values were below federal toxicity thresholds, but levels in Fever Creek exceeded the acute toxicity limit (Table 3). Surface or ground water runoff from Brooks is the suspected source of contamination. Again, the low concentration of PCP detected upstream of Fever Creek may be due to sample contamination.

Sediment Toxicant Scans

Most toxicants in water are adsorbed onto suspended particles which eventually settle and accumulate. Consequently, streambed sediments may provide a historical record of chemical conditions in the overlying water. Sediments were sampled at four sites in

Whatcom Creek. Results of toxicant scans are shown in Appendix G and summarized in Table 4. BNA detection limits were high due to sample dilution; detected compounds were reported as estimates because analytical holding times were exceeded by several months. Nonetheless, the data were judged to be "generally acceptable" after a quality assurance review (R. Farlow, EPA, personal communication).

Nine of ten metals detected in Whatcom Creek sediments increased between RM 1.7 and 1.4. Fever Creek (RM 1.45) is a likely contaminant source due to the prevalence of auto body and auto repair shops along its lower length. However, of the four sites sampled, RM 1.4 had the highest proportion of TOC and fines (clay). These two qualities greatly affect the ability of sediments to adsorb both inorganic and organic toxicants (Schults *et al.* 1987). Therefore elevated metals at RM 1.4 may simply be an artifact of higher TOC and/or fines.

Correlation analysis was performed to measure the association between individual metals and TOC/fines. No metals were correlated with percent clay, but five of ten were significantly correlated with TOC. All five showed an increase between RM 1.7 and 1.4, but after correction for TOC, none of the five upheld this pattern (Table 4). Even so, at least four of ten metals found in mainstem sediments increased in the reach which includes Fever Creek.

Of 19 BNA compounds detected in Whatcom Creek sediments, at least 11 increased in the Fever Creek reach, with levels declining farther downstream (Table 4). The remaining eight may exhibit similar behavior, but high detection limits obscured actual trends. Five of the BNA compounds detected were significantly correlated with TOC (none correlated with fines). Correction of the five for TOC did not alter the finding of peak BNA levels at RM 1.4. Although Lincoln Creek also discharges between RM 1.7 and 1.4, Fever Creek is considered the more likely source of contamination based on land use comparisons.

All but three of the BNA compounds detected were polycyclic aromatic hydrocarbons (PAHs). These chemicals are formed during incomplete combustion of fossil fuels; they are also found in petroleum products. As a result, PAHs are common constituents of road surface runoff. Sediment PAH levels in Whatcom Creek were higher than reported in several Seattle-area urban streams, but comparable to levels reported in urban stream sediments elsewhere (Galvin and Moore 1982).

Six pesticides were also detected in Whatcom Creek sediments (Table 4). Like the majority of BNA's, these six compounds were highest at RM 1.4, with levels declining downstream. The three organochlorine insecticides and the herbicide MCPA may have originated in either Lincoln or Fever Creek, but the chlorinated phenols probably derived from the latter (specifically, Brooks Lumber). As with water samples, a small amount of PCP was detected in mainstem sediments upstream of the Fever Creek confluence.

Invertebrate Communities

Mainstem macroinvertebrates were sampled on three occasions in an effort to trace entry points of toxicants to Whatcom Creek. Findings are presented in Appendix H. Two-way indicator species analysis (TWINSPAN) was performed to reduce and interpret the complex invertebrate data set. A brief description of this multivariate statistical method is provided in Appendix E.

TWINSPAN results are shown in Table 5. The tree-like dendrogram below each taxa-by-site table illustrates the similarity between sites. Similar sites are located on the same "branch" of the tree, while dissimilar sites occupy different branches.

In July, replicate riffle samples generally clustered together. The first major dendrogram division separates the two upstream sites from the three downstream sites. Upstream sites were erosional in nature, with coarse sediments and limited plant growth (Appendix I); mayflies and stoneflies were common. Downstream sites featured depositional habitats, with slower waters and greater primary production; worms, snails, mites, and amphipods were common.

July sampling of vegetative habitat also failed to evidence a toxicant source. The spring coho kill had occurred several months earlier, so affected reaches could have been recolonized in the interim. Like riffles, organisms at upstream and downstream vegetation sites were dissimilar. Note that RM 1.8 was an outlier in the TWINSPAN analysis; the character of instream vegetation at this site was different from other sites.

November invertebrate sampling occurred within days of the autumn coho kill. Riffle communities at the two middle sites differed from those at the upper- and lowermost sites, suggesting a toxic discharge below RM 1.8 with biological recovery by RM 0.7. However, all four sites had diverse communities, a feature which would not occur in the presence of a toxic discharge.

Of greater ecological significance was the presence of Perlidae, Baetidae, and Ancylidae at all riffle sites except RM 0.7. The former two families are typically considered sensitive to pollution, implicating a toxicant source between RM 1.1 and 0.7. November sampling of vegetative habitat yielded a similar finding: only amphipods were present at RM 0.7. As a result, this stream reach was targeted for additional biota work in December.

Fever Creek had no apparent impact on riffle and vegetative invertebrates at RM 1.4 in November. In fact, of five vegetation sites sampled, the right (impacted) and left bank communities at RM 1.4 were most similar (Table 5). Additional sampling was conducted farther upstream, directly below the Fever Creek confluence. No invertebrates were found among rocks and leaf litter in the tributary plume. Given the poor quality of Fever Creek, the absence of life came as no surprise; PCP was the likely toxicant. Biological recovery within a short distance downstream (RM 1.4R) is attributed to dilution by Whatcom Creek.

Invertebrate sampling in December was restricted to the vicinity of RM 0.7. The primary division of the dendrogram generally separates upstream and downstream sites from those in between. This pattern may represent localized toxicity associated with storm sewer discharges near State Street (RM 0.75). However, the picture is complicated by replicate and triplicate samples at RM 0.65, which clustered with mid-reach sites rather than upstream and downstream stations.

Overall, summer and winter sampling results indicate that invertebrates in Whatcom Creek were largely unaffected by the toxicant(s) responsible for the recurrent fish kills. Toxicity comparisons among taxonomic groups (i.e., invertebrates vs. fish) were rarely encountered in the literature, but several citations were noteworthy. Mance (1987) reported that where data were available, the insect larvae as a group were more resistant to metals than fish. Not unexpectedly, Mayer and Ellersieck (1986) determined that insects and crustaceans were more sensitive to insecticide exposure than fish. The comparative toxicity of BNA compounds and herbicides to different taxonomic groups was variable, with results being chemical-specific (Johnson and Finley 1980; Millemann *et al.* 1984; Mayer and Ellersieck 1986; Eisler 1987). For PCP, Zischke *et al.* (1985) found macroinvertebrate communities to be more tolerant than fish.

SUMMARY AND CONCLUSIONS

Recurrent coho salmon kills at MHFH were investigated by Ecology in 1987. Hatchery water is drawn from Whatcom Creek, an urban stream draining Lake Whatcom and much of downtown Bellingham. Coho mortality appeared to be associated with the "first flush" of pollutants into the creek.

Dead coho had damaged gill filaments. A literature review showed that a wide range of toxicants produce this effect. Further review focused on bioassays pairing coho with other species reared at MHFH. On the whole, coho were more pollution-tolerant than the other species, but data were limited for some toxicants (e.g., heavy metals).

Water quality in Whatcom Creek was generally good during dry weather. Fecal contamination in the lower mainstem was caused by two municipal storm drains that probably contained raw sewage.

Water quality during wet weather was fair to poor, but the stream appeared capable of supporting fish life. Degradation was attributed to the cumulative impact of urban stormwater runoff. After considerable rainfall, mainstem water quality resembled that of in-flowing storm sewers.

Federal toxicity criteria for several metals were exceeded in Whatcom Creek in summer and winter. However, levels were below toxicity thresholds for coho. The stream was also contaminated with PCP; surface or ground water runoff from Brooks Lumber Co. (via Fever Creek) was the probable source. The wintertime concentration of PCP in Fever Creek exceeded the EPA acute toxicity criterion.

Hatchery sampling during kill events failed to identify the toxicant(s) responsible, but analyte scans were limited due to insufficient sample size. Metals, PCP, and several other organic compounds were detected at levels well below coho toxicity thresholds. Still, additive or synergistic effects may have been involved (available literature on this subject is scant). Also, retention time of water at MHFH is several hours, so sampling could have occurred after a more toxic "slug" of contaminant passed through the facility.

Whatcom Creek sediments were contaminated with metals and various organic toxicants. Of the latter, PAHs predominated; these compounds are common constituents of urban (roadway) runoff. Chlorinated phenols, including PCP, were also present. Toxicant deposition patterns implicate Fever Creek as a likely source of metals and organics contamination.

Except for localized impacts in the Fever Creek plume, invertebrate sampling failed to identify toxicant entry points. Lack of community changes along Whatcom Creek may indicate stream invertebrates are more tolerant than coho to the agent(s) causing the recurrent kills. A literature review showed metals and PCP were generally more toxic to fish than invertebrates.

In conclusion, the recurrent coho kills at MHFH appear to be associated with the first flush of pollutants into Whatcom Creek. First flush runoff typically features the highest concentration of contaminants, with pollutant loads being a function of antecedent dry days and rainfall quantity. The water quality degradation in Whatcom Creek serves as a classic example of the hazard inherent in using small streams as conduits of urban stormwater runoff.

Heavy metal toxicity from multiple sources is strongly implicated in the recurrent kills. However, PCP toxicity may also play a role. During dry periods, toxicants likely accumulate in the many storm sewers and ditches tributary to Whatcom Creek. Heavy rainfall would abruptly flush these contaminants into the mainstem, exerting a shock pollutant load on both the creek and hatchery.

RECOMMENDATIONS

The most easily implemented solution to the recurrent kills is to close the hatchery intake at the onset of a kill event. Unfortunately, this practice has proven ineffective in the past. An alternate solution is to cease withdrawals during the first several rain events which succeed prolonged dry spells (water can be recirculated within the facility for 1-2 days). The primary argument against this proposal is cost. MHFH is a low-budget operation; the hatchery is only manned on a part-time basis. Recirculation requires that someone be on-site full-time in case of pump failure, but funding is not available for such a contingency.

Other remedies include pretreatment of rearing water or development of an alternate water supply. Neither are cost-effective. The hatchery manager has recently experimented with transferring coho out of the facility prior to the wet season. At present, this practice appears to offer the best means of preventing the recurrent kills.

Ultimately, the solution to this problem lies with pollution abatement in the Whatcom Creek watershed. Action on this front is scheduled to begin shortly. The Puget Sound Water Quality Management Plan (PSWQA 1987) requires that the six largest cities in the Puget Sound basin, including Bellingham, begin developing stormwater pollution control programs by July 1, 1989. Program elements will include monitoring of problem storm drains, investigation and remediation of illegal discharges, and implementation of best management practices to control stormwater pollution.

In the meantime, NWRO and MHFH should undertake the following actions:

- Hatchery water should be resampled during the next autumn coho kill. The hatchery manager has been equipped with sufficient sample containers to enable complete conventional and priority pollutant scans.

- Histopathology results should be confirmed by John Morrison of the U. S. Fish and Wildlife Service in Olympia. The hatchery manager should collect both healthy and dying (<u>not dead</u>) coho during the next kill event. Whole fish should be preserved in Bouin's Fixative for 24 hours, then placed in 70 percent ethanol for transport (body cavities should be carefully incised prior to fixing).

- The proposed Urban Embayment Action Team of NWRO's North Sound District should further investigate the nature and source of: (1) fecal pollution in two municipal storm sewers; (2) elevated lead and copper in Whatcom Creek; and (3) PCP contamination in Fever Creek.

REFERENCES

Alabaster, J.S., and R. Lloyd, 1982. Water quality criteria for fresh water fish. 2nd ed. Butterworths, London, U.K. 361 pp.

APHA *et al.* (American Public Health Association, American Water Works Association, and Water Pollution Control Federation), 1985. Standard methods for the examination of water and wastewater. 16th ed. Washington D.C. 1268 pp.

Brown, V.M., 1968. The calculation of the acute toxicity of mixtures of poisons to rainbow trout. Water Res. 2:723-733.

Call, D.J., L.T. Brooke, and R.J. Kent, 1983. Toxicity, bioconcentration, and metabolism of five herbicides in freshwater fish. U.S. Environ. Prot. Agency report EPA-600/3-83-096. Duluth, MN. 99 pp.

Chapman, G.A., 1975. Toxicity of copper, cadmium and zinc to Pacific Northwest salmonids. Cited in: Lorz, H.W., R.H. Williams, and C.A. Fustish. 1978. Effects of several metals on smolting of coho salmon. EPA report 600/3-78-090. Corvallis, OR. 85 pp.

Chapman, G.A., and D.G. Stevens, 1978. Acutely lethal levels of cadmium, copper, and zinc to adult male coho salmon and steelhead. Trans. Am. Fish. Soc. 107(6):837-840.

Cole, R.H., R.E. Frederick, R.P. Healy, and R.G. Rolan, 1984. Preliminary findings of the priority pollutant monitoring project of the nationwide urban runoff program. J. Water Pollut. Control Fed. 56(7):898-908.

Davis, J.C., and R.A.W. Hoos, 1975. Use of sodium pentachlorophenate and dehydroabietic acid as reference toxicants for salmonid bioassays. J. Fish. Res. Board Can. 32:411-416.

Drotts, J.V., 1980. Location of point sources of pollution for Whatcom Creek, Whatcom County, Washington. Huxley College, Bellingham, WA. 17 pp. (unpubl. manuscript)

Eisler, R., 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Rep. 85 (1.11). Laurel, MD. 81 pp.

Eller, L.L., 1975. Gill lesions in freshwater teleosts. pp. 305-330 in W.E. Ribelin and G. Migaki (eds.). The pathology of fishes. Univ. of Wisconsin Press, Madison. 1004 pp.

EPA, 1980. Ambient water quality criteria for phthalate esters. EPA report 440/5-80-067. Washington D.C. 102+ pp.

EPA, 1983. Methods for chemical analysis of water and wastes. EPA 600/4-79-020. Cincinnati, OH.

EPA, 1986. Quality criteria for water. EPA report 440/5-86-001. Washington D.C.

Evans, D.H., 1987. The fish gill: site of action and model for toxic effects of environmental pollutants. Environ. Health Perspect. 71:47-58.

Galvin, D.V., and R.K. Moore, 1982. Toxicants in urban runoff. Metro Toxicant Program Report No. 2, Seattle, WA. 230+ pp.

Gordon, M.R., and D.J. McLeay, 1977. Sealed-jar bioassays for pulpmill effluent toxicity: effects of fish species and temperature. J. Fish. Res. Board Can. 34:1389-1396.

Hill, M.O., 1979. TWINSPAN: A Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, NY. 90 pp.

Holme, N.A., and A.D. McIntyre, 1971. Methods for the study of marine benthos. Blackwell Scientific Publications, London, U.K. 334 pp.

Huntamer, D., 1986. Laboratory user's manual. Washington State Dept. of Ecology, Manchester, WA. 139 pp.

Iwama, G.K., and G.L. Greer, 1980. Effect of a bacterial infection on the toxicity of sodium pentachlorophenate to juvenile coho salmon. Trans. Am. Fish. Soc. 109:290-292.

Johnson, W.W., and H.O. Sanders, 1977. Chemical forest fire retardants: acute toxicity to five freshwater fishes and a scud. U.S. Fish and Wildlife Service Technical Paper 91. Washington D.C. 7 pp.

Johnson, W.W., and M.T. Finley, 1980. Handbook of acute toxicity of chemicals to fish and aquatic invertebrates. U.S. Fish and Wildlife Service Resource Publication 137. Washington, D.C. 98 pp.

Kittle, L., 1981. Whatcom Creek freshwater resource damage assessment, January 7-8, 1981. Ecology memorandum of 4/7/81 to L. Taylor. 12+ pp.

Lorz, H.W., and B.P. McPherson, 1976. Effects of copper or zinc in fresh water on the adaptation to sea water and ATPase activity, and the effects of copper on migratory disposition of coho salmon (*Oncorhynchus kisutch*). J. Fish. Res. Board Can. 33:2023-2030.

Lorz, H.W., R.H. Williams, and C.A. Fustish, 1978. Effects of several metals on smolting of coho salmon. EPA report 600/3-78-090. Corvallis, OR. 85 pp.

Lorz, H.W., S.W. Glenn, R.H. Williams, C.M. Kunkel, L.A. Norris, and B.R. Loper, 1979. Effects of selected herbicides on smolting of coho salmon. EPA-600/3-79-071. Corvallis, OR. 103 pp.

Mallatt, J., 1985. Fish gill structural changes induced by toxicants and other irritants: a statistical review. Can. J. Fish. Aquat. Sci. 42:630-648.

Mance, G., 1987. Pollution threat of heavy metals in aquatic environments. Elsevier Applied Science, London, U.K. 372 pp.

Marking, L.L., and T.D. Bills, 1977. Chlorine: its toxicity to fish and detoxification of antimycin. Investigations in Fish Control No. 74. U.S. Dept. Int. Fish and Wildl. Serv., Washington D.C. 5 pp.

Mayer, F.L., Jr., and M.R. Ellersieck, 1986. Manual of acute toxicity: interpretation and data base for 410 chemicals and 66 species of freshwater animals. U.S. Fish and Wildlife Service Resource Publ. 160. Washington, D.C. 579 pp.

McKague, A.B., and R.B. Pridmore, 1978. Toxicity of altosid and dimilin to juvenile rainbow trout and coho salmon. Bull. Environ. Contam. Toxicol. 20:167-169.

Merritt, R.W., and K.W. Cummins (eds.), 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publishing Co., Dubuque, IA. 441 pp.

Millemann, R.E., W.J. Birge, J.A. Black, R.M. Cushman, K.L. Daniels, P.J. Franco, J.M. Giddings, J.F. McCarthy, and A.J. Stewart, 1984. Comparative acute toxicity to aquatic organisms of components of coal derived synthetic fuels. Trans. Am. Fish. Soc. 113:74-85.

Moles, A., S.D. Rice, and S. Korn, 1979. Sensitivity of Alaskan freshwater and anadromous fishes to Prudhoe Bay crude oil and benzene. Trans. Am. Fish. Soc. 108:408-414.

Olson, L.E., and L.L. Marking, 1975. Toxicity of four toxicants to green eggs of salmonids. Prog. Fish Cult. 37(3):143-147.

Pennak, R.W., 1978. Fresh-water invertebrates of the United States. 2nd ed. John Wiley and Sons, New York, NY. 803 pp.

Post, G., and T.R. Schroeder, 1971. The toxicity of four insecticides to four salmonid species. Bull. Environ. Contam. Toxi. 6(2):144-154.

PSWQA (Puget Sound Water Quality Authority), 1987. Puget Sound Water Quality Management Plan. Seattle, WA.

Schults, D.W., S.P. Ferraro, G.R. Ditsworth, and K.A. Sercu, 1987. Selected chemical contaminants in surface sediments of Commencement Bay and the Tacoma Waterways, Washington, USA. Mar. Environ. Res. 22:271-295.

STSC, Inc., 1986. Statgraphics statistical graphics system. Rockville, MD.

Tetra Tech, Inc., 1986. Recommended protocols for measuring conventional sediment variables in Puget Sound. Report to EPA. Bellevue, WA. 46 pp.

Zischke, J.A., J.W. Arthur, R.O. Hermanutz, S.F. Hedtke, and J.C. Helgen, 1985. Effects of pentachlorophenol on invertebrates and fish in outdoor experimental channels. Aquat. Toxicol. 7:37-58.

Segment No. 01-01-99

INVESTIGATION OF RECURRENT COHO SALMON MORTALITY AT THE MARITIME HERITAGE FISH HATCHERY IN BELLINGHAM, WASHINGTON

by
Will Kendra

Washington State Department of Ecology
Water Quality Investigations Section
Olympia, Washington 98504-6811

June 1988

FIGURES

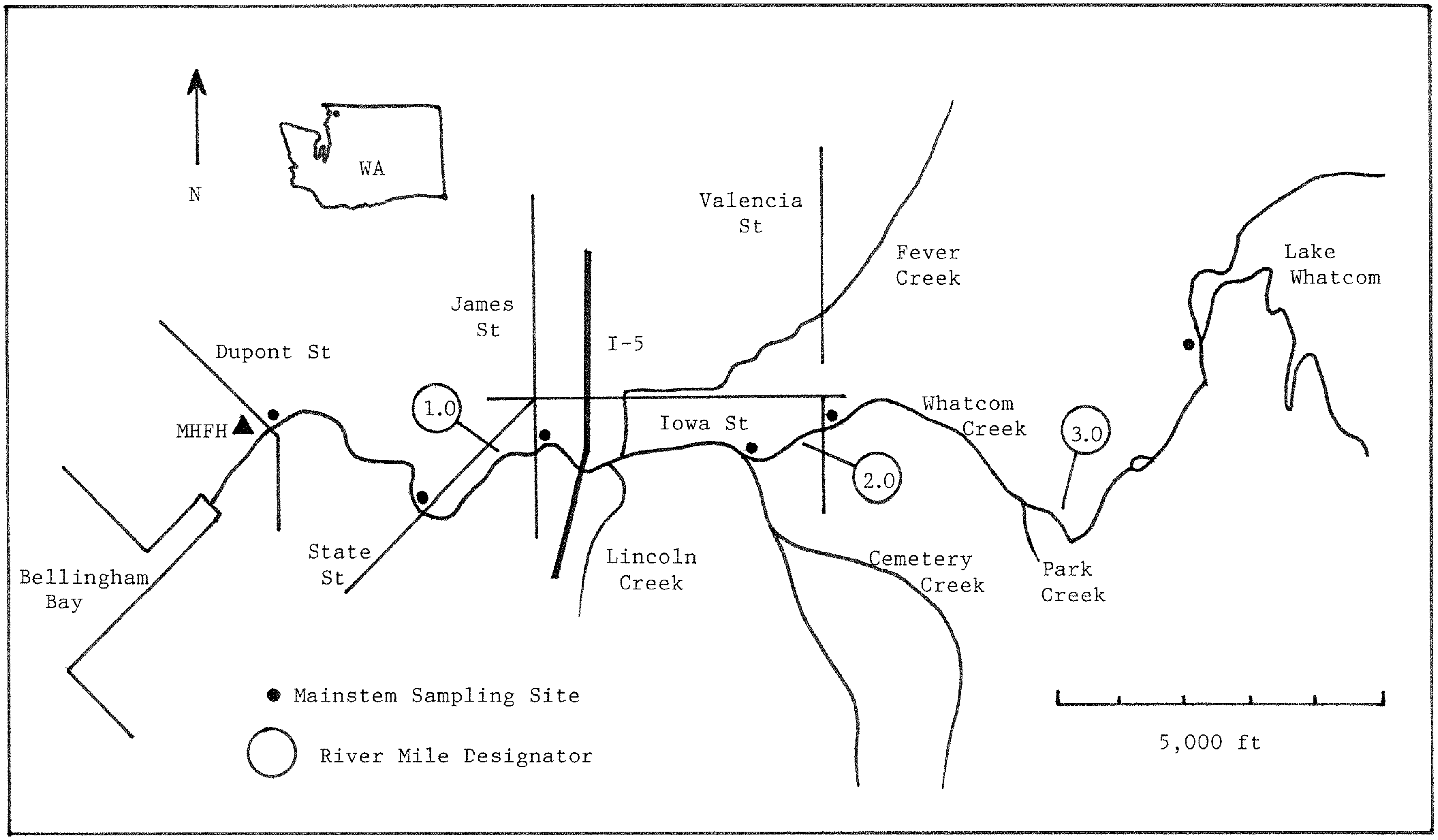
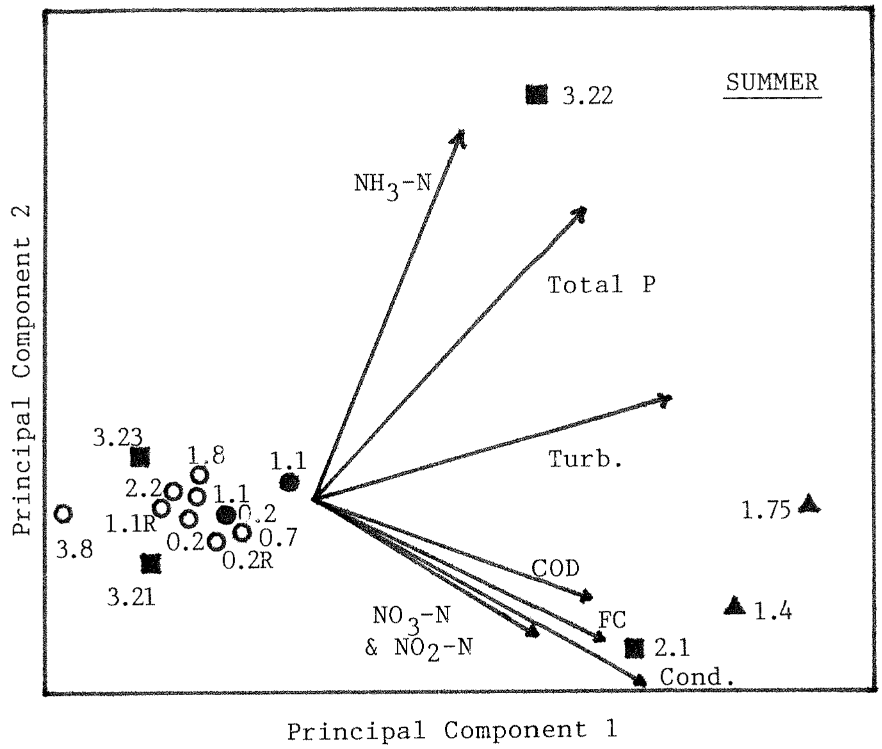


Figure 1. Map of Whatcom Creek showing location of mainstem sampling sites.



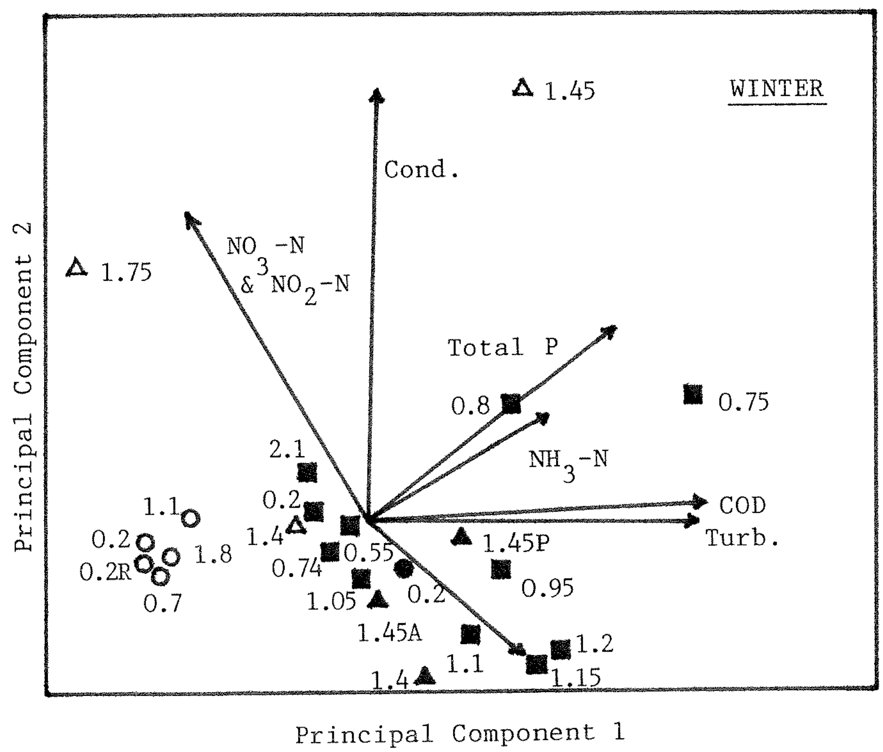


Figure 2. Scatterplot of principal component scores for sites sampled during the July and December 1987 surveys of Whatcom Creek. Numerals denote river mile; mainstem, tributary, and pipe sites are coded O, △, and □ respectively; unshaded sites sampled on first day (7/14 or 12/8), shaded sites on second (7/15 or 12/9); R = Replicate; A = Morning; P = Afternoon. Note the poor quality of most inflows.

TABLES

Table 1. Summary of toxicity bioassays pairing coho salmon with either chinook salmon or rainbow/steelhead trout under similar test conditions (adapted from Appendix B).

Class of Compound	Coho more sensitive than other species	Coho and other species equally sensitive/ tolerant	Coho more tolerant than other species
Piscicides	-	2	-
Fungicides	-	1	1
Herbicides	1	2	-
Organochlorine Insecticides	2	2	1
Organophosphorous Insecticides	-	4	3
Carbamate Insecticides	-	1	2
Pyrethroid Insecticides	1	1	1
Other Insecticides	2	-	1
Fire Retardants*	-	2	2
Aromatic Hydrocarbons	-	2	-
Heavy Metals**	-	1.5	0.5
Miscellaneous	-	--	2
Totals	6	18.5	13.5
Percent	16%	49%	36%

*Toxic action believed to be due to un-ionized ammonia (Johnson and Sanders 1977).

**Result of copper bioassay shared by two categories due to lack of 95 percent confidence interval for steelhead.

Table 2. Concentrations of heavy metals in Whatcom Creek in July and December 1987. Federal "Goldbook" criteria (EPA 1986) and 96-hour LC_{50}s for coho salmon are provided for reference.

Sampling Site	River Mile*	Date	Time	Discharge cfs**	Hardness mg/L	Cadmium	Chromium***	Copper	Lead	Nickel	Zinc
						Metal Concentration in ug/L					
Mainstem											
50 m above Dupont Street	0.2	7/14	0845	29.6	44	<0.2	<5	<5	<1	<5	14
		7/15	1455	25.4	37	0.3	<5	<5	<1	<5	<5
		12/8	1015	24.8	35	<0.2	<1	13 A	<1	<5	2
		12/9	1400	85.3	39	<0.2	<5	6 C	7 C	<5	48 C
50 m below State Street	0.7	7/14	0945	27.7	30	<0.2	<5	<5	18 A	<5	6
		12/8	1100	28.5	32	<0.2	<1	17 A	<1	25	11
20 m above James Street	1.1	7/14	1030	29.9	40	<0.2	<5	<5	10 C	<5	<5
		7/15	1425	25.5	42	0.3	<5	13 A	<1	<5	<5
		12/8	1220	32.6	37	<0.2	<1	17 A	<1	<5	17
20 m above end of Racine St.	1.8	7/14	1200	27.7	40	0.6 C	<5	<5	<1	<5	<5
		12/8	1255	23.4	27	<0.2	<1	15 A	<1	<5	<1
100 m above Valencia Street	2.2	7/14	1230	28.4	34	<0.2	<5	<5	4 C	<5	<5
10 m below Lake Whatcom Dam	3.8	7/14	1315	20.4	39	<0.2	<5	<5	1 C	<5	22
Tributaries											
Mouth of Lincoln Creek	(1.4)	12/9	0915	8.2	36	<0.2	<5	4	21 C	<5	25
Mouth of Fever Creek	(1.45)	12/9	0925	5.5	26	<0.2	<5	<1	6 C	<5	93 A
Pipes											
40 m above Dupont Street	(0.2)	12/9	0955	[0.3]	29	<0.2	<5	12 A	2 C	<5	28
Under Cornwall Avenue	(0.55)	12/9	1015	[0.4]	31	<0.2	<5	5 C	4 C	<5	63 A
Under State Street	(0.75)	12/9	1045	0.2	27	<0.2	<5	25 A	11 C	<5	120 A
2 m below James Street	(1.1)	12/9	1200	[0.4]	28	<0.2	<5	13 A	490 A	<5	95 A
Between King St. & I-5	(1.2)	12/9	1245	2.0	25	<0.2	<5	16 A	31 A	<5	120 A
1 m below Valencia Street	(2.1)	12/9	0830	4.8	48	<0.2	<5	<1	96 A	<5	40
Federal Goldbook Criteria											
Acute (1-hour average concentration)					25	0.82	16	4.8	14	440	36
					35	1.2	16	6.6	21	580	48
					45	1.6	16	8.4	30	720	59
Chronic (4-day average concentration)					25	0.38	11	3.6	0.54	49	33
					35	0.50	11	4.8	0.84	65	44
					45	0.61	11	6.0	1.2	80	54
Coho Salmon 96-hour LC50s											
Chapman (1975)					20-30E	2.7	--	--	--	--	--
Lorz and McPherson (1976)					89-99	--	--	74	--	--	4,600
Chapman and Stevens (1978)					19-26	--	--	46	--	--	900
Lorz *et al*. (1978)					84-98	10.4	>5,000	--	--	>5,000	--

* Parentheses indicate river mile where tributary or pipe joins Whatcom Creek.
** Brackets indicate flows are estimates.
*** Results of present survey and Lorz *et al*. (1978) reported as total chromium; Goldbook values are the more restrictive hexavalent criteria.
A = Exceeds federal acute toxicity criterion at observed hardness level.
C = Exceeds federal chronic toxicity criterion at observed hardness level.
E = Estimated.

Table 3. Concentration of pentachlorophenol (PCP) in and near Whatcom Creek in 1987. Federal "Goldbook" criteria (EPA 1986) and 96-hour LC_{50}s for coho salmon are provided for reference.

Sampling Site	River Mile*	Date	pH (S.U.)	PCP (ug/L)
Maritime Heritage Hatchery				
Pond 0	--	05/01	--	0.58B
	--	05/02	--	0.11B
Pond 2	--	05/01	--	0.33B
	--	05/02	--	0.09B
	--	11/14	6.8	0.14
	--	11/16	--	0.15
Settling Pond	--	05/04	--	<0.010B
Mainstem Whatcom Creek				
50 m above Dupont Street	0.2	07/14	8.0**	0.019
		12/08	6.6	0.032
50 m below State Street	0.7	12/08	6.7	0.051
20 m above James Street	1.1	07/14	7.8	0.011
		12/08	6.8	0.063
20 m above end of Racine Street	1.8	07/14	7.7	0.023
		12/08	6.6	0.016
Tributaries				
Mouth of Fever Creek	(1.45)	12/09	6.6	10
Federal Goldbook Criteria				
Acute (1-hour average concentration)			6.5	5.5
			7.0	9.1
			7.5	15
			8.0	25
Chronic (4-day average concentration)			6.5	3.5
			7.0	5.7
			7.5	9.5
			8.0	16
Coho Salmon 96-hour LC50s				
Davis and Hoos (1975) ***			7.0	30
			7.0	85
Iwama and Greer (1980)			6.9-7.5	60

* Parentheses indicate river mile where tributary joins Whatcom Creek.
** Estimated.
*** Reported values were test results from two different laboratories.
B = Method blank contamination (see Appendix F).

Table 4. Sediment quality at four sites in Whatcom Creek on July 16, 1987. Data are from Appendix G: only toxicants exceeding the minimum detection limit are listed, excluding analytes showing blank contamination. Wet-weight results were converted to a dry-weight basis; TOC-corrected data are provided for parameters showing significant ($p<0.05$) correlation with TOC.

Parameter	Units	Site 0.2	0.7	1.4	1.7
Total Solids	Pcnt wet wt	77.7	75.5	57.6	82.6
Total Organic Carbon	Pcnt dry wt	1.0	0.4	4.0	0.8
Grain size - Clay (<4um)	Pcnt dry wt	3.1	0.7	3.4	2.2
METALS					
Arsenic	mg/kg dry wt	3.3	3.1	6.1	4.9
Beryllium	"	0.29	0.18	0.50	0.26
Cadmium	"	0.30	0.22	0.61	0.13
Chromium	"	24	26	40	25
Copper	"	22	13	47	12
Lead	"	58	50	75	5
Mercury	"	0.049	0.042	0.071	0.040
Nickel	"	27	21	35	23
Silver	"	0.74	1.5	0.07	<0.02
Zinc	"	110	72	170	45
Beryllium	mg/kg TOC	29	45	12	32
Chromium	"	2,400	6,500	1,000	3,100
Copper	"	2,200	3,200	1,200	1,500
Mercury	"	4.9	10	1.8	5
Nickel	"	2,700	5,200	880	2,900
BASE-NEUTRAL/ACID COMPOUNDS					
Acenaphthene	ug/kg dry wt	19J	24J	140J	<310
Acenaphthylene	"	55J	<1,600	<15,000	<310
Anthracene	"	44J	56J	780J	<310
Anthracene, benzo(a)-	"	110J	170J	2,600J	<310
Chrysene	"	120J	210J	2,800J	31J
Dibenzofuran	"	44J	24J	<15,000	<310
Fluoranthene	"	300J	440J	6,900J	56J
Fluoranthene, benzo(b)-	"	190J	240J	3,800J	<310
Fluoranthene, benzo(k)-	"	<1,600	230J	<15,000	<310
Fluorene	"	36J	40J	450J	<310
Naphthalene	"	270J	<1,600	<15,000	17J
Naphthalene, 2-methyl-	"	33J	<1,600	280J	6J
Perylene, benzo(g,h,i)-	"	<1,600	120J	<15,000	30J
Phenanthrene	"	260J	320J	4,500J	42J
Phenol	"	<1,600	<1,600	710J	<310
Phthalate, butylbenzyl-	"	120J	<1,600	6,200J	<310
Pyrene	"	300J	410J	6,600J	93J
Pyrene, benzo(a)-	"	<1,600	160J	2,100J	<310
Pyrene, indeno(1,2,3-c,d)-	"	79J	130J	1,500J	<310
Chrysene	ug/kg TOC	12,000J	52,000J	70,00J	3,900J
Fluoranthene	"	30,000J	110,000J	170,000J	7,000J
Naphthalene, 2-methyl-	"	3,300J	<400,000	7,000J	750J
Phenanthrene	"	26,000J	80,000J	110,000J	5,200J
Pyrene	"	30,000J	100,000J	160,000J	12,000J
ORGANOCHLORINE PESTICIDES					
BHC, gamma- (Lindane)	ug/kg dry wt	<2	<2	66	<2
DDT, 4,4'-	"	<2	<2	12	<2
Endosulfan sulfate	"	13	15	500	<2
HERBICIDES					
MCPA	ug/kg dry wt	<130	500	570	<130
Phenol, pentachloro-	"	8	5	240	1
Phenol, tetrachloro-	"	5	1M	10	<2
Phenol, pentachloro-	ug/kg TOC	800	1,200	6,000	120

J = Estimated value.
M = Presence of material verified but not quantified.

Table 5. Results of TWINSPAN analyses of macroinvertebrate data from Whatcom Creek, 1987. Organism abundance is coded as R = Rare (1-4), C = Common (5-25), and A = Abundant (>25). Sampling sites are coded to river mile, where r = replicate, t = triplicate, and R or L = sampling biased to right or left bank (facing downstream).

July: 5-Rock

Taxa	0.2r	0.7	0.2	0.7r	1.1r	1.1	2.2r	2.2	1.8r	1.8
Planorbidae	C	C	R	R	-	-	-	-	-	R
Elmidae	R	R	-	-	-	-	-	-	-	-
Lymnaeidae	R	R	-	R	-	-	-	-	-	-
Oligochaeta	R	C	-	A	R	-	-	-	-	-
Lepidostomatidae	R	-	R	-	-	-	-	-	-	-
Haliplidae	-	R	R	R	-	-	-	-	-	-
Physidae	R	R	R	R	-	-	-	-	-	-
Tipulidae	R	C	R	C	R	R	-	-	-	-
Empididae	-	R	-	R	R	-	-	-	-	-
Hydroptilidae	-	-	-	C	R	R	-	-	-	-
Hydracarina	C	A	C	C	C	C	-	-	-	R
Ancylidae	R	R	-	C	A	A	R	-	-	-
Limnephilidae	R	R	R	-	-	-	-	-	R	-
Hydropsychidae	R	-	-	R	-	-	-	-	R	-
Chironomidae	C	A	C	C	C	C	-	R	R	R
Glossosomatidae	C	A	R	A	C	C	C	C	R	R
Gammaridae	C	C	C	C	R	C	C	R	R	C
Rhyacophilidae	-	R	R	R	-	-	R	R	-	-
Polycentropodidae	-	-	R	-	-	-	R	-	-	-
Heptageniidae	-	-	-	-	C	A	C	A	C	C
Perlodidae	-	R	-	-	R	R	R	R	R	R
Baetidae	-	-	-	A	-	C	C	A	C	A
Nemouridae	-	-	-	-	-	-	-	R	R	R
Simuliidae	-	-	-	-	-	-	R	R	R	-
Philopotamidae	-	-	-	-	-	-	R	R	-	R
Leptophlebiidae	-	-	-	-	-	-	-	-	R	R

July: Vegetation

Taxa	0.2	0.7	2.2	1.1	1.8
Lepidostomatidae	C	R	-	-	R
Hirudinea	R	R	-	-	-
Coenagrionidae	C	C	-	-	-
Ancylidae	R	R	-	-	-
Lymnaeidae	C	C	-	-	-
Physidae	C	C	-	-	-
Chironomidae	C	R	C	C	-
Gammaridae	R	C	C	C	-
Simuliidae	-	-	R	R	C
Baetidae	C	C	C	R	R

November: Vegetation

Taxa	1.8	1.1	1.4L	1.4R	0.7
Baetidae	C	R	-	R	-
Chironomidae	C	C	R	R	-
Perlodidae	-	R	R	-	-
Gammaridae	A	-	R	R	R

November: Riffle Kick

Taxa	1.1	1.4R	1.8	0.7
Hydracarina	R	R	-	-
Haliplidae	R	R	-	R
Perlidae	R	R	R	-
Baetidae	A	A	A	-
Ancylidae	R	R	R	-
Heptageniidae	C	R	C	R
Perlodidae	C	R	R	C
Tipulidae	-	R	-	R
Physidae	-	R	-	C
Gammaridae	R	C	C	A
Chironomidae	R	C	C	A
Nemouridae	R	-	C	-
Oligochaeta	-	-	R	R
Hydropsychidae	-	-	R	R
Sialidae	-	-	R	R

December: Riffle Kick

Taxa	0.95	1.1	0.96	0.65	0.71	0.65t	0.74	0.75r	0.75t	0.65r	0.75
Zygoptera *	R	-	R	-	-	-	-	-	-	-	-
Perlidae	R	R	R	-	-	-	-	-	-	-	-
Chironomidae	C	C	R	R	R	-	-	-	-	-	-
Heptageniidae	R	R	R	-	-	-	-	-	-	-	R
Nemouridae	C	R	R	R	-	-	R	-	-	-	-
Perlodidae	R	R	R	R	R	R	-	-	-	-	-
Baetidae	R	C	C	-	C	-	R	R	R	-	-
Sialidae	-	-	R	-	R	R	-	-	-	-	-
Gammaridae	R	C	C	C	C	R	R	R	C	-	R
Hirudinea	-	-	-	R	R	-	-	-	-	-	R
Physidae	-	-	-	C	C	R	-	-	-	C	R
Coleoptera *	R	-	-	R	-	-	-	R	-	R	R
Oligochaeta	-	R	R	R	R	R	R	-	R	R	-
Planorbidae	R	-	-	R	C	R	C	R	-	R	-
Trichoptera *	R	-	R	R	R	C	R	-	-	R	-
Tipulidae	C	R	-	-	-	R	-	R	R	R	-
Ancylidae	R	-	-	-	-	-	R	R	-	R	R
Glossosomatidae	-	-	-	-	-	C	C	C	-	R	R
Rhyacophilidae	-	-	-	-	-	-	-	R	R	-	-

*Families were not identified due to field constraints.

APPENDICES

Appendix A. Sampling frequency and locales during 1987 Whatcom Creek surveys.

Sampling Site	RM*	Date	Time**	Matrix		Parameter***																							
				H2O	Sed	Q	Temp	pH	Cond	O2	Turb	COD	Nuts (3)	FC	Hdns	Met (6)	Met PP	BNA	PCB	O-Cl Pest	O-P Pest	PCP	Brom	Herb	Sol	TOC	GSA	Bugs	Hab
Mainstem																													
Vicinity of Dupont St	0.2	7/16	1000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
		7/16	Repl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
20 m above Dupont St	0.2	7/16	1000	-	X	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	-	-	X	X	X	X	-	-
50 m above Dupont St	0.2	7/14	0845	X	-	X	X	-	X	X	X	X	X	X	X	X	-	-	-	-	-	X	X	-	-	-	-	-	-
		7/14	Repl	X	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7/15	1455	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
		12/8	1015	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	X	-	-	-	-	-
		12/8	Repl	X	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		12/9	1400	X	-	X	X	X	X	-	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Vicinity of old BNRR bridge	0.65	12/7	1410	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		12/7	Repl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		12/7	Trip	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
50 m below State St	0.7	7/14	0945	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
		7/16	1200	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
		7/16	Repl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		11/24	--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		12/7	1310	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		12/8	1100	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	X	-	-	-	-	-
20 m below State St	0.7	7/16	1100	-	X	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	-	-	X	X	X	X	-	-
20 m below State St, above storm drain	0.7	12/7	1325	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Between State St and Ellis St storm drains	0.75	12/7	1340	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		12/7	Repl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		12/7	Trip	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
Vicinity of Meador Ave	0.95	12/7	1450	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
20 m above James St	1.1	7/14	1030	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	X	X	-	-	-	-	-	-
		7/14	Repl	X	-	-	-	-	-	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		7/15	1425	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
		7/16	1400	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
		7/16	Repl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		11/24	--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		12/7	1530	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		12/8	1220	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	X	-	-	-	-	-

Sampling Site	RM*	Date	Time**	Matrix H2O	Matrix Sed	Q	Temp	pH	Cond	O2	Turb	COD	Nuts (3)	FC	Hdns	Met (6)	Met PP	BNA	PCB	O-Cl Pest	O-P Pest	PCP	Brom	Herb	Sol	TOC	GSA	Bugs	Hab
Mainstem - continued																													
5 m below mouth of Lincoln Cr	1.4	7/16	1600	-	X	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	-	-	X	X	X	X	-	-
5 m above mouth of Lincoln Cr	1.4	11/24	--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
50 m below mouth of Cemetery Cr	1.7	7/16	1500	-	X	-	-	-	-	-	-	-	-	-	-	-	X	X	X	X	X	-	-	X	X	X	X	-	-
		7/16	Repl	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	X	-	-
20 m above end of Racine St	1.8	7/14	1200	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	X	X	-	-	-	-	-	-
		7/16	1540	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
		7/16	Repl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		11/24	--	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
		12/8	1255	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	X	-	-	-	-	-
100 m above Valencia St	2.2	7/14	1230	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
		7/16	1650	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X
		7/16	Repl	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-
10 m below Lk Whatcom dam	3.8	7/14	1315	X	-	X	X	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Tributaries																													
Mouth of Lincoln Cr	(1.4)	7/15	1125	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		12/8	1345	X	-	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		12/9	0915	X	-	X	X	X	X	-	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Mouth of Fever Cr	(1.45)	12/8	1430	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		12/9	0925	X	-	X	X	X	X	-	X	X	X	X	X	X	-	-	-	-	-	-	-	X	-	-	-	-	-
		12/9	1320	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mouth of Cemetery Cr	(1.75)	7/15	1215	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		12/8	1310	X	-	X	X	X	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pipes																													
40 m above Dupont St	(0.2)	12/9	0955	X	-	X	X	X	X	-	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Under Cornwall Ave	(0.55)	12/9	1015	X	-	X	X	X	X	-	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix A. Continued.

Sampling Site	RM*	Date	Time**	Matrix H2O	Matrix Sed	Q	Temp	pH	Cond	O2	Turb	COD	Nuts (3)	FC	Hdns	Met (6)	Met PP	BNA	PCB	O-Cl Pest	O-P Pest	PCP	Brom	Herb	Sol	TOC	GSA	Bugs	Hab
Pipes - Continued.																													
20 m below State St	(0.75)	12/9	1110	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Under State St	(0.75)	7/15	0920	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		12/9	1045	X	-	X	X	X	X	-	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
1 m above Ellis St	(0.8)	7/15	0930	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		12/9	1050	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 m below Meador Ave	(0.95)	12/9	1145	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
End of Iron St	(1.05)	12/9	1220	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 m below James St	(1.1)	12/9	1200	X	-	X	X	X	X	-	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
End of King St	(1.15)	12/9	1300	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Between King St and I-5	(1.2)	12/9	1245	X	-	X	X	X	X	-	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
1 m below Valencia St	(2.1)	7/15	1150	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		12/9	0830	X	-	X	X	X	X	-	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-
Screen-house overflow	(3.21)	7/15	1315	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WDW Hatchery (18-inch pipe)	(3.22)	7/15	1300	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WDW Hatchery (overland flow)	(3.23)	7/15	1250	X	-	X	X	X	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix A. Continued.

Sampling Site	RM*	Date	Time**	Matrix: H2O	Sed	Parameter***: Q	Temp	pH	Cond	O2	Turb	COD	Nuts (3)	FC	Hdns	Met (6)	Met PP	BNA	PCB	O-Cl Pest	O-P Pest	PCP	Brom	Herb	Sol	TOC	GSA	Bugs	Hab
Maritime Heritage Hatchery																													
Settling Pond	--	5/4	--	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-
Pond No. 0	--	5/1	--	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-
		5/2	--	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-
Pond No. 2	--	5/1	--	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-
		5/2	--	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-	-	-	-
		11/14	0900	X	-	-	X	X	-	X	-	-	-	-	-	X	-	-	-	-	-	-	-	X	-	-	-	-	-
		11/16	0945	X	-	-	-	-	-	-	-	-	-	-	-	X	-	X	-	-	-	-	-	X	-	-	-	-	-

* Parentheses indicate river mile where tributary or pipe joins Whatcom Creek.

** Repl = Replicate sample.
Trip = Triplicate sample.

*** Q = Discharge
Temp = Temperature
Cond = Conductivity
O2 = Dissolved Oxygen
Turb = Turbidity
COD = Chemical Oxygen Demand
Nuts (3) = Nutrients: NH3-N, NO3-N/NO2-N, Total P
FC = Fecal Coliform
Hdns = Hardness
Met (6) = Total Metals: Cd,Cr, Cu,Pb,Ni,Zn
Met PP = 13 Priority Pollutant Metals (Total)
BNA = Base-Neutral/Acid Organics
PCB = Polychlorinated Biphenyls
O-Cl Pest = Organochlorine Pesticides
O-P Pest = Organophosphorus Pesticides
PCP = Pentachlorophenol
Brom = Bromacil
Herb = Herbicides
Sol = Percent Solids
TOC = Total Organic Carbon
GSA = Grain Size Analysis
Bugs = Macroinvertebrates
Hab = Habitat Assessment

Appendix B. Comparison of the relative toxicity of various chemical compounds to coho salmon versus chinook salmon and/or rainbow/steelhead trout. To minimize variability associated with water chemistry, physical factors, etc., only paired bioassay results are reported. All test organisms were juveniles, except for the two heavy metal bioassays (adults). Most tests were static. For compounds tested more than once, the more recent result was used.

Compound	Species	96-hr LC50 (95% Conf. Int.)	Reference
Piscicides			
Antimycin A	Coho	18 ng/L (12-28)	Johnson and
	Rainbow	12 ng/L (7-23)	Finley (1980)
TFM	Coho	2.70 mg/L (2.26-3.22)	Olson and
	Chinook	2.24 mg/L (1.94-2.59)	Marking (1975)
Fungicides			
Captan	Coho	138 ug/L (118-161)	Johnson and
	Chinook	56.5 ug/L (52.3-61.0)	Finley (1980)
	Rainbow	73.2 ug/L (66.6-80.4)	
Folpet	Coho	106 ug/L (82-137)	Johnson and
	Rainbow	39 ug/L (18-85)	Finley (1980)
Herbicides			
2,4,5-T (Silvex)	Coho	0.6 mg/L (0.45-0.79)	Mayer and
	Rainbow	17.2 mg/L (14-21)	Ellersieck (1986)
Dinitramine	Coho	600 ug/L (503-715)	Johnson and
	Rainbow	820 ug/L (625-1,075)	Finley (1980)
Sodium Penta-chlorophenate	Coho	92 ug/L (79.3-106.7)	Davis and
	Rainbow	98 ug/L (87.5-109.8)	Hoos (1975)
Chlorinated Hydrocarbon Insecticides			
Chlordane	Coho	14 ug/L (11-17)	Johnson and
	Rainbow	42 ug/L (37-48)	Finley (1980)
DDT	Coho	4.0 ug/L (3.0-6.0)	Johnson and
	Rainbow	8.7 ug/L (6.8-11.1)	Finley (1980)
Endrin	Coho	0.76 ug/L (0.64-0.90)	Post and
	Rainbow	0.40 ug/L (0.33-0.50)	Schroeder (1971)
Lindane	Coho	23 ug/L (19-28)	Johnson and
	Rainbow	27 ug/L (20-36)	Finley (1980)
Toxaphene	Coho	8 ug/L (6-10)	Johnson and
	Rainbow	10.6 ug/L (7.9-12.7)	Finley (1980)

Appendix B. Continued.

Compound	Species	96-hr LC50 (95% Conf. Int.)	Reference
Organophosphorus Insecticides			
Azinphos Methyl	Coho	6.1 ug/L (5.0-7.4)	Johnson and
	Rainbow	4.3 ug/L (3.0-6.4)	Finley (1980)
Fenitrothion	Coho	5.0 mg/L (4.1-6.1)	Johnson and
	Rainbow	2.4 mg/L (2.0-2.9)	Finley (1980)
Fenthion	Coho	1.32 mg/L (1.02-1.68)	Johnson and
	Rainbow	0.93 mg/L (0.75-1.15)	Finley (1980)
Malathion	Coho	170 ug/L (160-180)	Johnson and
	Rainbow	200 ug/L (160-240)	Finley (1980)
Methyl Parathion	Coho	5.3 mg/L (4.9-5.6)	Johnson and
	Rainbow	3.7 mg/L (3.13-4.38)	Finley (1980)
Phoxim	Coho	407 ug/L (327-507)	Johnson and
	Rainbow	180 ug/L (119-272)	Finley (1980)
Temephos	Coho	0.35 mg/L (0.23-0.33)	Johnson and
	Rainbow	0.16 mg/L (0.10-0.24)	Finley (1980)
Carbamate Insecticides			
Carbaryl	Coho	4.34 mg/L (3.31-5.69)	Johnson and
	Rainbow	1.95 mg/L (1.45-2.63)	Finley (1980)
Carbofuran	Coho	530 ug/L (432-650)	Johnson and
	Rainbow	380 ug/L (272-531)	Finley (1980)
Mexacarbate	Coho	23.0 mg/L (19.7-26.9)	Johnson and
	Rainbow	12.0 mg/L (10.3-14.0)	Finley (1980)
Pyrethroid Insecticides			
d-trans	Coho	2.6 ug/L (1.8-3.5)	Johnson and
Allethrin	Steelhead	9.7 ug/L (8.0-11.6)	Finley (1980)
Pyrethrum	Coho	23.0 ug/L (17.8-29.6)	Mayer and
	Rainbow	20.0 ug/L (13.0-30.6)	Ellersieck (1986)
	Steelhead	22.5 ug/L (19.2-26.3)	
RU-11679	Coho	0.63 ug/L (0.58-0.69)	Mayer and
	Steelhead	0.11 ug/L (0.09-0.13)	Ellersieck (1986)

Appendix B. Continued.

Compound	Species	96-hr LC50 (95% Conf. Int.)	Reference
<u>Other Insecticides</u>			
Altosid	Coho Rainbow	86 mg/L (81-91) 106 mg/L (92-121)	McKague and Pridmore (1978)
SD-16898	Coho Rainbow	0.38 mg/L (0.32-0.45) 3.40 mg/L (2.65-4.36)	Mayer and Ellersieck (1986)
SD-17250	Coho Rainbow	3.1 mg/L (2.3-4.1) 1.5 mg/L (1.0-2.2)	Johnson and Finley (1980)
<u>Fire Retardants</u>			
Fire-trol 100	Coho Rainbow	780 mg/L (602-1,010) 1,000 mg/L (863-1,200)	Mayer and Ellersieck (1986)
Fire-trol 931	Coho Rainbow	1,000 mg/L (943-1,060) 940 mg/L (796-1,110)	Johnson and Finley (1980)
Phos-chek 202	Coho Rainbow	320 mg/L (279-367) 230 mg/L (204-259)	Johnson and Finley (1980)
Phos-chek 259	Coho Rainbow	250 mg/L (220-283) 160 mg/L (150-171)	Mayer and Ellersieck (1986)
<u>Aromatic Hydrocarbons</u>			
Benzene	Coho Chinook	14.1 mg/L (9.9-18.3) 11.7 mg/L (8.4-13.6)	Moles <u>et</u> <u>al</u>. (1979)
Crude Oil, Water-Soluble Fraction	Coho Chinook	1.45 mg/L (1.36-1.54) 1.47 mg/L (1.37-1.57)	Moles <u>et</u> <u>al</u>. (1979)
<u>Heavy Metals</u>			
Copper*	Coho Steelhead	46 ug/L (44-49) 35 ug/L (?)	Chapman and Stevens (1978)
Zinc*	Coho Steelhead	905 ug/L (636-1,210) 735 ug/L (?)	Chapman and Stevens (1978)

Appendix B. Continued.

Compound	Species	96-hr LC50 (95% Conf. Int.)	Reference
Miscellaneous Compounds			
Bleached Kraft Mill Effluent	Coho	17.4% BKME (16.5-18.3)	Gordon and McLeay (1977)
	Rainbow	14.2% BKME (13.1-15.1)	
Chlorine	Coho	0.29 mg/L (0.23-0.37)	Marking and Bills (1977)
	Rainbow	0.17 mg/L (0.15-0.20)	

* To allow comparison to coho results, Chapman and Stevens adjusted 96-hour LC50 values for steelhead to a hardness of 20 mg/L using the hardness-mortality relationship obtained from the data of Brown (1968).

Appendix C. Partial list of tributaries, storm sewer outfalls, and other discharges to Whatcom Creek (sewer data from B. McCourt, Bellingham Public Works, personal communication).

River Mile	Bank**	Site	Description
0.2*	R	40 m NE of Dupont Street Bridge	27-inch storm sewer draining extensive residential/commercial area N of crk
0.25	R	W side of Grand Avenue Bridge	8-inch storm sewer draining part of B St
0.3	R	20 m W of Commercial Street Bridge	8-inch storm sewer draining part of A Street
0.5	L	50 m W of Cornwall Avenue Bridge	Small storm sewer draining Unity St and part of Champion St
0.5	L	20 m W of Cornwall Avenue Bridge	Small storm sewer draining 2-block area S of creek
0.55*	R	Under Cornwall Avenue Bridge	21-inch storm sewer draining extensive residential/commercial area bordering Cornwall Ave
0.65	R	NE side of old BNRR Bridge	24-inch storm sewer draining vicinity of former BNRR rail bed to NE
0.75*	R	20 m NW of State Street Bridge	18-inch storm sewer draining extensive residential/commercial area bordering Ellis St
0.75*	R	Under State Street Bridge	22-inch storm sewer draining extensive commercial area along State St
0.8*	L	E side of Ellis Street Bridge	24-inch storm sewer draining extensive residential/commercial area bordering Ellis St
0.85	L,R	Between Ellis St and Meador Avenue Bridges	3 small storm drains serving 2-block residential area S of creek; also 1 serving local commercial area NW of creek
0.95*	L	S side of Meador Avenue Bridge	24-inch storm sewer draining extensive residential area along Humboldt St
0.95	R	Under Meador Avenue Bridge	Small storm sewer draining local commercial area NW of creek
1.05*	R	End of Iron Street	30-inch storm sewer draining commercial area near Iron and Ohio Sts
1.1*	R	W side of James Street Bridge	24-inch storm sewer draining extensive residential/commercial area along James St
1.1	L	10 m NE of James Street Bridge	8-inch pipe draining Diehl Ford property
1.15	R	20 m W of end of King Street	Small storm sewer draining local commercial area N of creek
1.15*	R	End of King Street	12-inch storm sewer draining local commercial area on King St
1.2*	R	Between King Street and I-5 Bridge	28-inch storm sewer draining extensive residential/commercial area along Lincoln St
1.2	L	W side of I-5 Bridge	12- and 36-inch storm drains serving I-5
1.3	L	100 m E of I-5 Bridge	2 small drains serving Haskell Corp. property
1.4*	L	Lincoln Creek	Natural and stormwater drainage from extensive residential/commercial area S to Lakeway Dr and beyond; portions of the stream flow underground
1.45*	R	Fever Creek	Primarily stormwater drainage from extensive commercial/light industrial area along Iowa St and vicinity; also drains a residential area upstream to Valencia St; portions of the stream flow underground, including the terminal downstream reach which passes through a 60-inch pipe
1.75*	L	Cemetery Creek	Natural and stormwater drainage of extensive rural and residential areas S and SE of creek to Lakeway Dr and beyond
2.1*	R	W side of Valencia Street Bridge	54-inch storm sewer draining a commercial/light industrial area along Valencia St; also includes natural and stormwater drainage diverted from residential areas along upper Fever Creek
3.21*	L	Whatcom Falls Park near WDW Hatchery	40-inch pipe discharging screen-house overflow from municipal water plant; effluent flows down concrete raceway to creek
3.22*	L	Whatcom Falls Park near WDW Hatchery	18-inch pipe discharging WDW fish hatchery effluent
3.23*	L	Whatcom Falls Park near WDW Hatchery	Overland flow of effluent from WDW fish hatchery

*Sites sampled in the present study.
**Left or right bank facing downstream.

Appendix D. Concentrations and loads of conventional water quality variables in Whatcom Creek in July and December 1987.

Sampling Site	River Mile*	Date	Time	Discharge cfs**	Temp. deg.C	pH s.u.	Cond. umhos/cm	Diss. Ox. mg/L	Diss. Ox. % sat	Turbidity NTU	COD mg/L	COD lbs/day	NH3-N mg/L	NH3-N lbs/day	NO3-N & NO2-N mg/L	NO3-N & NO2-N lbs/day	Total P mg/L	Total P lbs/day	Fecal Coliform #/100 mL	Fecal Coliform Thou./sec
Mainstem																				
50 m above Dupont St	0.2	7/14	0845	29.6	18.8	--	87	8.95	95	<1	10	1,600	<0.01	<1.6	0.22	35	0.02	3.2	120	1,000
		7/14	Repl	--	--	--	--	--	--	<1	11	1,800	<0.01	<1.6	0.21	34	0.02	3.2	200	1,700
		7/15	1455	25.4	20.3	8.3	105	10.60	116	<1	22	3,000	0.01	1.4	0.18	25	0.02	2.7	110	800
		12/8	1015	24.8	8.4	6.6	120	11.30	96	3	8	1,100	0.02	2.7	0.48	64	0.03	4.0	290	2,000
		12/8	Repl	--	--	--	--	--	--	2	8	1,100	0.02	2.7	0.48	64	0.03	4.0	410	2,900
		12/9	1400	85.3	8.4	6.9	90	--	--	13	45	21,000	0.04	18	0.38	170	0.05	23	630	15,000
50 m below State St	0.7	7/14	0945	27.7	19.0	8.0	97	9.60	103	<1	15	2,200	0.01	1.5	0.21	31	0.02	3.0	200	1,600
		12/8	1100	28.5	8.5	6.7	110	11.60	99	3	9	1,400	0.02	3.1	0.47	72	0.03	4.6	600	4,900
20 m above James St	1.1	7/14	1030	29.9	19.6	7.8	100	9.70	105	1	13	2,100	<0.01	<1.7	0.21	34	0.02	3.2	9	77
		7/14	Repl	--	--	--	--	--	--	<1	12	1,900	<0.01	<1.7	0.22	35	0.02	3.2	20	170
		7/15	1425	25.5	19.7	7.8	85	9.70	105	2	19	2,600	<0.01	<1.4	0.20	28	0.02	2.8	21	150
		12/8	1220	32.6	8.7	6.8	130	11.30	97	5	12	2,100	0.02	3.5	0.47	83	0.04	7.0	220	2,000
20 m above end of Racine St	1.8	7/14	1200	27.7	19.5	7.7	97	9.15	99	<1	14	2,100	0.01	1.5	0.23	34	0.03	4.5	14	110
		12/8	1255	23.4	8.9	6.6	85	11.70	101	2	5	630	0.01	1.3	0.34	43	0.05	6.3	71	470
100 m above Valencia St	2.2	7/14	1230	28.4	19.7	7.8	80	9.05	98	<1	14	2,100	0.02	3.1	0.24	37	0.02	3.1	15	120
10 m below Lk Whatcom dam	3.8	7/14	1315	20.4	22.5	7.9	70	9.25	107	<1	18	2,000	<0.01	<1.2	0.10	11	<0.01	<1.2	3	17
Tributaries																				
Mouth of Lincoln Cr	(1.4)	7/15	1125	[0.02]	16.6	7.5	440	--	--	2	67	[7]	0.01	[<0.1]	0.17	[<1]	0.03	[<0.1]	130	[<1]
		12/8	1345	0.8	8.2	6.5	145	10.60	90	12	25	110	0.03	0.1	0.45	2	0.04	0.2	450	100
		12/9	0915	8.2	7.3	6.4	85	--	--	19	20	880	0.03	1.3	0.25	11	0.04	1.8	2,000	4,700
Mouth of Fever Cr	(1.45)	12/8	1430	0.4	8.8	6.6	555	--	--	24	42	91	0.10	0.2	0.64	1	0.08	0.2	730	83
		12/9	0925	5.5	7.5	6.6	115	--	--	20	23	680	0.04	1.2	0.39	12	0.03	0.9	1,200	1,900
		12/9	1320	7.7	8.3	6.7	120	--	--	24	37	1,500	0.05	2.1	0.44	18	0.05	2.1	830	1,800
Mouth of Cemetery Cr	(1.75)	7/15	1215	[<0.01]	14.3	7.5	210	--	--	3	23	[<2]	0.06	[<0.1]	0.41	[<1]	0.04	[<0.1]	430	[<2]
		12/8	1310	2.2	7.7	6.7	190	10.60	89	4	18	210	0.01	0.1	1.51	18	0.03	0.4	96	60
Pipes																				
40 m above Dupont St	(0.2)	12/9	0955	[0.3]	8.8	6.8	87	--	--	13	15	[24]	0.04	[<0.1]	0.61	[<1]	0.06	[<0.1]	800	[68]
Under Cornwall Ave	(0.55)	12/9	1015	[0.4]	8.8	6.5	92	--	--	14	19	[41]	0.06	[0.1]	0.96	[2]	0.05	[0.1]	2,300	[260]
20 m below State St	(0.75)	12/9	1110	[0.2]	8.4	6.8	90	--	--	19	22	[24]	0.04	[<0.1]	0.45	[<1]	0.04	[<0.1]	240	[14]
Under State St	(0.75)	7/15	0920	0.01	18.0	7.6	410	--	--	13	110	6	18	1.0	0.55	<1	0.97	<0.1	92,000J	260J
		12/9	1045	0.2	8.2	6.9	115	--	--	21	53	57	2.98	3.2	0.41	<1	0.08	<0.1	770	44
1 m above Ellis St	(0.8)	7/15	0930	0.07	22.9	7.3	170	--	--	17	150	57	0.40	0.2	0.66	<1	1.2	0.5	26,000J	520J
		12/9	1050	[1.0]	9.1	6.9	110	--	--	13	41	[220]	0.05	[0.3]	0.52	[3]	0.12	[0.6]	670	[190]
2 m below Meador Ave	(0.95)	12/9	1145	[0.3]	8.5	7.0	85	--	--	17	34	[55]	0.05	[<0.1]	0.37	[<1]	0.08	[0.1]	1,600	[140]
End of Iron St	(1.05)	12/9	1220	1.8	8.8	6.9	110	--	--	15	35	340	0.06	0.6	0.49	5	0.03	0.3	1,100	560
2 m below James St	(1.1)	12/9	1200	[0.4]	8.8	6.9	65	--	--	22	37	[80]	0.04	[<0.1]	0.19	[<1]	0.05	[0.1]	800	[91]
End of King St	(1.15)	12/9	1300	0.2	9.8	6.9	35	--	--	17	59	64	0.06	<0.1	0.08	<1	0.06	<0.1	830	47
Between King St and I-5	(1.2)	12/9	1245	2.0	8.2	6.7	53	--	--	20	60	650	0.07	0.8	0.21	2	0.05	0.5	1,200	680
1 m below Valencia St	(2.1)	7/15	1150	0.04	16.2	7.9	340	--	--	1	24	5	<0.01	<0.1	0.47	<1	0.03	<0.1	280	3
		12/9	0830	4.8	7.7	6.2	120	--	--	9	22	570	0.02	0.5	0.80	21	0.06	1.6	1,300	1,800
Screen-house overflow	(3.21)	7/15	1315	2.9	15.3	7.5	87	--	--	<1	14	220	<0.01	<0.2	0.31	5	<0.01	<0.2	<1	<1
WDW Hatchery (18-inch pipe)	(3.22)	7/15	1300	[2.7]	18.7	7.3	67	--	--	2	18	[260]	0.20	[2.9]	0.18	[3]	0.08	[1.2]	2	[2]
WDW Hatchery (overland flow)	(3.23)	7/15	1250	3.3	18.1	7.5	74	--	--	<1	17	300	0.06	1.1	0.18	3	0.01	0.2	1	<1

* Parentheses indicate river mile where tributary or pipe joins Whatcom Creek.
** Brackets indicate flows (and thus loads) are estimates.
J = Estimated value.

Appendix E. Brief description of multivariate statistical techniques used in the present study as an aid to data interpretation.

Water quality is a multivariate concept--it is not defined by any single constituent (variable), but rather by a number of variables. Multivariate statistics are appropriate tools for analysis of water quality and biological data. Multivariate methods help clarify complex data sets to allow a better understanding of their underlying structure.

Most multivariate statistical techniques fall under the broad categories of ordination and classification. Ordination procedures reduce a multidimensional swarm of data points onto a two-dimensional graphic in such a way that any real pattern in the data may become apparent. Classification methods, or cluster analyses, formally divide entities (e.g., sampling sites) into groups on the basis of similarity in order to detect any natural groupings.

Principal components analysis (PCA) is an ordination technique that reduces the most important features of a data set to a few "principal components" that describe the intrinsic structure of the original data. These principal components may account for most of the variability in the original data set, allowing the remaining information to be discarded as noise. Mathematically, the principal components are essentially linear combinations of those parameters most responsible for the variation among different sampling sites. The first principal component is that linear combination of the original variables which best discriminates among the sites (i.e., accounts for the most variation).

Results of PCA are plotted on a two-dimensional graph, where each axis represents one principal component. Each sampling site is represented on the graph by a point whose coordinates are that site's first and second principal component scores. The relative position of sampling sites on the graph indicates their similarity: points (sites) close together are more similar than those far apart.

The relationship between the original water quality variables and the principal components can be superimposed on the graph as lines radiating outward from a central point. The length of each line is proportional to that variable's contribution to the principal components. Lines that parallel a component axis represent variables which are strongly correlated with that principal component. Similarly, the angle between any two lines is inversely proportional to the correlation between those two variables (i.e., lines pointing in the same direction indicate high correlation).

PCA was performed on summer and winter subsets of the original water quality data set (Appendix D) using the microcomputer program "Statgraphics" (STSC, Inc., 1986).

The data were first edited to delete parameters which were correlated with time of sampling (temperature, pH, and oxygen) or river mile (discharge and load). Remaining parameters were standardized to z scores for equal weighting (values below detection were set at one-half the detection limit).

Two-way indicator species analysis (TWINSPAN) is another multivariate statistical technique which reduces the complexity of a data set to clarify its underlying structure. TWINSPAN simultaneously performs an ordination (reciprocal averaging) and a classification (polythetic divisive clustering). With biological data, the resulting output is an ordered taxa-by-site table that groups similar sites together.

TWINSPAN was performed on subsets of the original benthic macroinvertebrate data set (Appendix H) using the Fortran program of Hill (1979). Only taxa detected at more than one site (within a data subset) were treated statistically. "Pseudospecies cut levels" were coded as: Rare (1-4 organisms) = 1; Common (5-25 organisms) = 2; and Abundant (>25 organisms) = 3.

Appendix F. Toxicants detected in water samples collected in and near Whatcom Creek in 1987. "Pond" designates Maritime Heritage Fish Hatchery rearing pond No. 0 or No. 2, or the initial settling pond at the hatchery.

		Date and Site														
		5/1		5/2		5/4	7/14			11/14*	11/16*	12/8				12/9
Parameter	Units	Pond No.0	Pond No.2	Pond No.0	Pond No.2	Settling Pond	RM 0.2	RM 1.1	RM 1.8	Pond No.2	Pond No.2	RM 0.2	RM 0.7	RM 1.1	RM 1.8	Fever Creek
CONVENTIONALS																
Temperature	deg. C	--	--	--	--	--	--	--	--	11.1	--	--	--	--	--	--
pH	S.U.	--	--	--	--	--	--	--	--	6.8	--	--	--	--	--	--
Dissolved Oxygen	mg/L	--	--	--	--	--	--	--	--	10.5	--	--	--	--	--	--
METALS																
Cadmium	ug/L	--	--	--	--	--	--	--	--	<0.2	<0.2	--	--	--	--	--
Chromium	"	--	--	--	--	--	--	--	--	<1	<1	--	--	--	--	--
Copper	"	--	--	--	--	--	--	--	--	5	1	--	--	--	--	--
Lead	"	--	--	--	--	--	--	--	--	<1	<1	--	--	--	--	--
Nickel	"	--	--	--	--	--	--	--	--	11	<5	--	--	--	--	--
Zinc	"	--	--	--	--	--	--	--	--	8	6	--	--	--	--	--
HERBICIDES																
2,4-D	ug/L	--	--	--	--	--	--	--	--	<0.1	<0.1	<0.020	<0.020	<0.020	<0.020	<0.020
2,4-DB	"	--	--	--	--	--	--	--	--	<0.1	<0.1	<0.020	<0.020	<0.020	<0.020	<0.020
2,4,5-T	"	--	--	--	--	--	--	--	--	<0.05	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010
2,4,5-TB	"	--	--	--	--	--	--	--	--	<0.05	<0.05	<0.010	<0.010	<0.010	<0.010	<0.010
2,4,5-TP (Silvex)	"	--	--	--	--	--	--	--	--	<0.05	<0.05	<0.010	<0.010	<0.010	<0.010	<2.0
Bromacil	"	49.4	50.0	2.6	2.25	0.14	<0.010	0.010M	0.010M	--	--	--	--	--	--	--
Bromoxynil	"	--	--	--	--	--	--	--	--	<0.05	<0.05	<0.010	<0.010	<0.010	<0.010	<0.10
Dicamba	"	--	--	--	--	--	--	--	--	0.22	0.24	0.020M	0.023	0.051	<0.010	<0.10
Dinoseb	"	--	--	--	--	--	--	--	--	<0.05	<0.05	<0.010	<0.010	<0.010	<0.010	<0.10
Ioxynil	"	--	--	--	--	--	--	--	--	<0.05	<0.05	<0.010	<0.010	<0.010	<0.010	<0.10
MCPA	"	--	--	--	--	--	--	--	--	<1.0	<1.0	<0.20	<0.20	<0.20	<0.20	<2.0
MCPB	"	--	--	--	--	--	--	--	--	<1.0	<1.0	<0.20	<0.20	<0.20	<0.20	<2.0
MCPP	"	--	--	--	--	--	--	--	--	<1.0	<1.0	<0.20	<0.20	<0.20	<0.20	<2.0
Phenol, pentachloro-	"	0.58B	0.33B	0.11B	0.09B	<0.010B	0.019	0.011	0.023	0.14	0.15	0.032	0.051	0.063	0.016	10
Phenol, tetrachloro-	"	--	--	--	--	--	--	--	--	0.019	0.035	0.020M	0.020M	0.010M	<0.010	0.16
Picloram	"	--	--	--	--	--	--	--	--	<0.05	<0.05	<0.010	<0.010	<0.010	<0.010	<0.10
Spike: 2,4-D	Pcnt recov.	--	--	--	--	--	--	--	--	--	--	--	--	--	18	--
Spike: 2,4,5-T	"	--	--	--	--	--	--	--	--	--	--	--	--	--	31	--
Spike: 2,4,5-TP	"	--	--	--	--	--	--	--	--	118	--	--	--	--	98	--
Spike: Dicamba	"	--	--	--	--	--	--	--	--	--	--	--	--	--	54	--
BASE-NEUTRAL/ACID COMPOUNDS																
Acenaphthene	ug/L	--	--	--	--	--	--	--	--	--	<0.6	--	--	--	--	--
Acenaphthylene	"	--	--	--	--	--	--	--	--	--	<0.1	--	--	--	--	--
Aniline, 2-nitro-	"	--	--	--	--	--	--	--	--	--	<1.6	--	--	--	--	--
Aniline, 3-nitro-	"	--	--	--	--	--	--	--	--	--	<0.9	--	--	--	--	--
Aniline, 4-nitro-	"	--	--	--	--	--	--	--	--	--	<1.8	--	--	--	--	--
Aniline, 4-chloro	"	--	--	--	--	--	--	--	--	--	<0.9	--	--	--	--	--
Anthracene	"	--	--	--	--	--	--	--	--	--	<0.5	--	--	--	--	--
Anthracene, benzo(a)-	"	--	--	--	--	--	--	--	--	--	<1.3	--	--	--	--	--
Anthracene, dibenzo(a,h)-	"	--	--	--	--	--	--	--	--	--	<1.0	--	--	--	--	--
Benzene, 1,2-dichloro-	"	--	--	--	--	--	--	--	--	--	<0.1	--	--	--	--	--
Benzene, 1,3-dichloro-	"	--	--	--	--	--	--	--	--	--	<0.2	--	--	--	--	--
Benzene, 1,4-dichloro-	"	--	--	--	--	--	--	--	--	--	<0.4	--	--	--	--	--
Benzene, 1,2,4-trichloro-	"	--	--	--	--	--	--	--	--	--	<0.9	--	--	--	--	--
Benzene, hexachloro-	"	--	--	--	--	--	--	--	--	--	<0.9	--	--	--	--	--
Benzene, nitro-	"	--	--	--	--	--	--	--	--	--	<0.5	--	--	--	--	--
Benzidine, 3,3'-dichloro-	"	--	--	--	--	--	--	--	--	--	<0.8	--	--	--	--	--
Benzoic acid	"	--	--	--	--	--	--	--	--	--	<1.7	--	--	--	--	--
Benzyl alcohol	"	--	--	--	--	--	--	--	--	--	<0.5	--	--	--	--	--
Butadiene, hexachloro-	"	--	--	--	--	--	--	--	--	--	<0.9	--	--	--	--	--
Chrysene	"	--	--	--	--	--	--	--	--	--	<0.3	--	--	--	--	--
Cyclopentadiene, hexachloro-	"	--	--	--	--	--	--	--	--	--	<0.8	--	--	--	--	--
Dibenzofuran	"	--	--	--	--	--	--	--	--	--	<0.8	--	--	--	--	--
Ethane, hexachloro-	"	--	--	--	--	--	--	--	--	--	<0.8	--	--	--	--	--
Ether, bis(2-chloroethyl)	"	--	--	--	--	--	--	--	--	--	<0.4	--	--	--	--	--
Ether, bis(2-chloroisopropyl)	"	--	--	--	--	--	--	--	--	--	<1.3	--	--	--	--	--
Ether, 4-bromophenyl-phenyl-	"	--	--	--	--	--	--	--	--	--	<0.6	--	--	--	--	--
Ether, 4-chlorophenyl-phenyl-	"	--	--	--	--	--	--	--	--	--	<0.7	--	--	--	--	--
Fluoranthene	"	--	--	--	--	--	--	--	--	--	<1.8	--	--	--	--	--
Fluoranthene, benzo(b)-	"	--	--	--	--	--	--	--	--	--	<0.5	--	--	--	--	--
Fluoranthene, benzo(k)-	"	--	--	--	--	--	--	--	--	--	<2.1	--	--	--	--	--
Fluorene	"	--	--	--	--	--	--	--	--	--	<0.6	--	--	--	--	--
Isophorone	"	--	--	--	--	--	--	--	--	--	<1.2	--	--	--	--	--
Methane, bis(2-chloroethoxy)	"	--	--	--	--	--	--	--	--	--	<1.2	--	--	--	--	--
Naphthalene	"	--	--	--	--	--	--	--	--	--	<1.6	--	--	--	--	--
Naphthalene, 2-chloro-	"	--	--	--	--	--	--	--	--	--	<0.1	--	--	--	--	--
Naphthalene, 2-methyl-	"	--	--	--	--	--	--	--	--	--	<0.9	--	--	--	--	--
Nitrosodiphenylamine, n-	"	--	--	--	--	--	--	--	--	--	<1.6n	--	--	--	--	--
Nitroso-di-n-propylamine, n-	"	--	--	--	--	--	--	--	--	--	<0.8	--	--	--	--	--
Perylene, benzo(g,h,i)-	"	--	--	--	--	--	--	--	--	--	<0.9	--	--	--	--	--
Phenanthrene	"	--	--	--	--	--	--	--	--	--	<0.8	--	--	--	--	--
Phenol	"	--	--	--	--	--	--	--	--	--	<0.4	--	--	--	--	--
Phenol, 2-chloro-	"	--	--	--	--	--	--	--	--	--	<0.5	--	--	--	--	--
Phenol, 2,4-dichloro-	"	--	--	--	--	--	--	--	--	--	<1.7	--	--	--	--	--
Phenol, 2,4,5-trichloro-	"	--	--	--	--	--	--	--	--	--	<0.4	--	--	--	--	--
Phenol, 2,4,6-trichloro-	"	--	--	--	--	--	--	--	--	--	<0.3	--	--	--	--	--
Phenol, pentachloro-	"	--	--	--	--	--	--	--	--	--	<0.6	--	--	--	--	--
Phenol, 4-chloro-3-methyl-	"	--	--	--	--	--	--	--	--	--	<0.9	--	--	--	--	--
Phenol, 2-methyl-	"	--	--	--	--	--	--	--	--	--	<0.6	--	--	--	--	--
Phenol, 4-methyl-	"	--	--	--	--	--	--	--	--	--	<0.3	--	--	--	--	--
Phenol, 2,4-dimethyl-	"	--	--	--	--	--	--	--	--	--	<1.4	--	--	--	--	--
Phenol, 2-nitro-	"	--	--	--	--	--	--	--	--	--	<1.6	--	--	--	--	--
Phenol, 4-nitro-	"	--	--	--	--	--	--	--	--	--	<1.0	--	--	--	--	--
Phenol, 2,4-dinitro-	"	--	--	--	--	--	--	--	--	--	<3.2	--	--	--	--	--
Phenol, 4,6-dinitro-2-methyl-	"	--	--	--	--	--	--	--	--	--	<3.3	--	--	--	--	--
Phthalate, bis(2-ethylhexyl)	"	--	--	--	--	--	--	--	--	--	0.7J	--	--	--	--	--
Phthalate, diethyl-	"	--	--	--	--	--	--	--	--	--	1.4b	--	--	--	--	--
Phthalate, dimethyl-	"	--	--	--	--	--	--	--	--	--	<0.5	--	--	--	--	--
Phthalate, di-n-butyl-	"	--	--	--	--	--	--	--	--	--	4.8	--	--	--	--	--
Phthalate, di-n-octyl-	"	--	--	--	--	--	--	--	--	--	<1.6	--	--	--	--	--
Phthalate, butylbenzyl-	"	--	--	--	--	--	--	--	--	--	<2.0	--	--	--	--	--
Pyrene	"	--	--	--	--	--	--	--	--	--	<1.6	--	--	--	--	--
Pyrene, benzo(a)-	"	--	--	--	--	--	--	--	--	--	<0.2	--	--	--	--	--
Pyrene, indeno(1,2,3-c,d)-	"	--	--	--	--	--	--	--	--	--	<0.9	--	--	--	--	--
Toluene, 2,4-dinitro-	"	--	--	--	--	--	--	--	--	--	<0.5	--	--	--	--	--
Toluene, 2,6-dinitro-	"	--	--	--	--	--	--	--	--	--	<1.3	--	--	--	--	--
Surrogate: Benzene, D5-nitro-	Pcnt recov.	--	--	--	--	--	--	--	--	--	69.7	--	--	--	--	--
Surrogate: Biphenyl, 2-fluoro-	"	--	--	--	--	--	--	--	--	--	69.5	--	--	--	--	--
Surrogate: Phenol, D5-	"	--	--	--	--	--	--	--	--	--	30.3	--	--	--	--	--
Surrogate: Phenol, 2-fluoro-	"	--	--	--	--	--	--	--	--	--	46.1	--	--	--	--	--
Surrogate: Phenol, 2,4,6-tribromo-	"	--	--	--	--	--	--	--	--	--	77.3	--	--	--	--	--
Surrogate: Terphenyl, D14-p-	"	--	--	--	--	--	--	--	--	--	54.3	--	--	--	--	--

* = Samples on 11/14 and 11/16 collected by hatchery manager.
b = Method blank contamination (2.6 ug/L diethylphthalate).
B = Method blank contamination (0.011 ug/L PCP; duplicate = <0.010 ug/L PCP).
J = Estimated value.
M = Presence of material verified but not quantified.
n = Cannot be separated from diphenylamine.

Appendix G. Results of toxicant scans on sediments collected in Whatcom Creek on July 16, 1987. Units shown are those reported by the laboratory.

Parameter	Units	Site 0.2	0.7	1.4	1.7	1.7 Repl
Total Solids	Pcnt wet wt	77.7	75.5	57.6	82.5	82.6
Total Organic Carbon	Pcnt dry wt	1.0	0.4	4.0	0.9	0.8
GRAIN SIZE						
Clay (<4um)	Pcnt dry wt	3.1	0.7	3.4	2.0	2.3
Silt (4um-62um)	"	6.5	1.6	8.6	4.0	4.0
Sand (62um-2mm)	"	55.1	94.0	85.2	47.8	49.1
Gravel (>2mm)	"	35.8	3.5	3.4	47.6	46.0
METALS						
Antimony	mg/kg dry wt	<0.1	<0.1	<0.1	<0.1	--
Arsenic	"	3.3	3.1	6.1	4.9	--
Beryllium	"	0.29	0.18	0.50	0.26	--
Cadmium	"	0.30	0.22	0.61	0.13	--
Chromium	"	24.1	25.8	39.6	24.8	--
Copper	"	21.5	13.1	46.6	11.6	--
Lead	"	58	50	75	5	--
Mercury	mg/kg wet wt	0.038	0.032	0.041	0.033	--
Nickel	mg/kg dry wt	26.6	21.1	35.2	22.9	--
Selenium	"	<0.1	<0.1	<0.1	<0.1	--
Silver	"	0.74	1.47	0.07	<0.02	--
Thallium	"	<0.1	<0.1	<0.1	<0.1	--
Zinc	"	107	72	170	45	--
BASE-NEUTRAL/ACID COMPOUNDS						
Acenaphthene	ug/kg wet wt	15J	18J	82J	<250	--
Acenaphthylene	"	43J	<1,200	<8,400	<250	--
Aniline, 2-nitro-	"	<5,800	<5,800	<41,000	<1,200	--
Aniline, 3-nitro-	"	<5,800	<5,800	<41,000	<1,200	--
Aniline, 4-nitro-	"	<5,800	<5,800	<41,000	<1,200	--
Aniline, 4-chloro	"	<1,200	<1,200	<8,400	<250	--
Anthracene	"	34J	42J	450J	<250	--
Anthracene, benzo(a)-	"	84J	130J	1,500J	<250	--
Anthracene, dibenzo(a,h)-	"	<1,200	<120	<8,400	<250	--
Benzene, 1,2-dichloro-	"	<1,200	<1,200	<8,400	<250	--
Benzene, 1,3-dichloro-	"	<1,200	<1,200	<8,400	<250	--
Benzene, 1,4-dichloro-	"	<1,200	<1,200	<8,400	<250	--
Benzene, 1,2,4-trichloro-	"	<1,200	<1,200	<8,400	<250	--
Benzene, hexachloro-	"	<1,200	<1,200	<8,400	<250	--
Benzene, nitro-	"	<1,200	<1,200	<8,400	<250	--
Benzidine, 3,3'-dichloro-	"	<2,400	<2,400	<17,000	<490	--
Benzoic acid	"	<5,800	<5,800	<41,000	<1,200	--
Benzyl alcohol	"	<1,200	<1,200	<8,400	<250	--
Butadiene, hexachloro-	"	<1,200	<1,200	<8,400	<250	--
Chrysene	"	90J	160J	1,600J	26J	--
Cyclopentadiene, hexachloro-	"	<1,200	<1,200	<8,400	<250	--
Dibenzofuran	"	34J	18J	<8,400	<250	--
Ethane, hexachloro-	"	<1,200	<1,200	<8,400	<250	--
Ether, bis(2-chloroethyl)	"	<1,200	<1,200	<8,400	<250	--
Ether, bis(2-chloroisopropyl)	"	<1,200	<1,200	<8,400	<250	--
Ether, 4-bromophenyl-phenyl-	"	<1,200	<1,200	<8,400	<250	--
Ether, 4-chlorophenyl-phenyl-	"	<1,200	<1,200	<8,400	<250	--
Fluoranthene	"	230J	330J	4,000J	46J	--
Fluoranthene, benzo(b)-	"	150J	180J	2,200J	<250	--
Fluoranthene, benzo(k)-	"	<1,200	170J	<8,400	<250	--
Fluorene	"	28J	30J	260J	<250	--
Isophorone	"	<1,200	<1,200	<8,400	<250	--
Methane, bis(2-chloroethoxy)	"	<1,200	<1,200	<8,400	<250	--
Naphthalene	"	210J	<1,200	<8,400	14J	--
Naphthalene, 2-chloro-	"	<1,200	<1,200	<8,400	<250	--
Naphthalene, 2-methyl-	"	26J	<1,200	160J	5J	--
Nitrosodiphenylamine, n-	"	<1,200	<1,200	<8,400	<250	--
Nitroso-di-n-propylamine, n-	"	<1,200	<1,200	<8,400	<250	--
Perylene, benzo(g,h,i)-	"	<1,200	91J	<8,400	25J	--
Phenanthrene	"	200J	240J	2,600J	35J	--
Phenol	"	<1,200	<1,200	410J	<250	--
Phenol, o-chloro-	"	<1,200	<1,200	<8,400	<250	--
Phenol, 2,4-dichloro-	"	<1,200	<1,200	<8,400	<250	--
Phenol, 2,4,5-trichloro-	"	<5,800	<5,800	<41,000	<1,200	--
Phenol, 2,4,6-trichloro-	"	<1,200	<1,200	<8,400	<250	--
Phenol, pentachloro-	"	<5,800	<5,800	<41,000	<1,200	--
Phenol, 4-chloro-3-methyl-	"	<1,200	<1,200	<8,400	<250	--
Phenol, 2-methyl-	"	<1,200	<1,200	<8,400	<250	--
Phenol, 4-methyl-	"	<1,200	<1,200	<8,400	<250	--
Phenol, 2,4-dimethyl-	"	<1,200	<1,200	<8,400	<250	--
Phenol, 2-nitro-	"	<1,200	<1,200	<8,400	<250	--
Phenol, 4-nitro-	"	<5,800	<5,800	<41,000	<1,200	--
Phenol, 2,4-dinitro-	"	<5,800	<5,800	<41,000	<1,200	--
Phenol, 4,6-dinitro-2-methyl-	"	<5,800	<5,800	<41,000	<1,200	--
Phthalate, bis(2-ethylhexyl)	"	380BJ	320BJ	4,400BJ	130BJ	--
Phthalate, diethyl-	"	<1,200	<1,200	<8,400	<250	--
Phthalate, dimethyl-	"	<1,200	<1,200	<8,400	<250	--
Phthalate, di-n-butyl-	"	33BJ	35BJ	210BJ	<250B	--
Phthalate, di-n-octyl-	"	63BJ	<1,200B	580BJ	30BJ	--
Phthalate, butylbenzyl-	"	97J	<1,200	3,600J	<250	--
Pyrene	"	230J	310J	3,800J	77J	--
Pyrene, benzo(a)-	"	<1,200	120J	1,200J	<250	--
Pyrene, indeno(1,2,3-c,d)-	"	61J	100J	890J	<250	--

Appendix G. Continued.

Parameter	Units	Site				
		0.2	0.7	1.4	1.7	1.7 Repl
BASE-NEUTRAL/ACID COMPOUNDS - continued						
Toluene, 2,4-dinitro-	ug/kg wet wt	<1,200	<1,200	<8,400	<250	--
Toluene, 2,6-dinitro-	"	<1,200	<1,200	<8,400	<250	--
Surrogate: Benzene, D5-nitro-	Pcnt recov.	93	78	68	45	--
Surrogate: Biphenyl, 2-fluoro-	"	94	84	86	63	--
Surrogate: Phenol, D5-	"	108	97	82	77	--
Surrogate: Phenol, 2-fluoro-	"	64	124	108	69	--
Surrogate: Pyrene, D10-	"	134	102	120	151	--
Surrogate: Terphenyl, D14-	"	135	116	124	58	--
POLYCHLORINATED BIPHENYLS						
PCB-1016	ug/kg wet wt	<10	<10	<50	<10	--
PCB-1221	"	<10	<10	<50	<10	--
PCB-1232	"	<10	<10	<50	<10	--
PCB-1242	"	<10	<10	<50	<10	--
PCB-1248	"	<10	<10	<50	<10	--
PCB-1254	"	<10	<10	<50	<10	--
PCB-1260	"	<10	<10	<50	<10	--
ORGANOCHLORINE PESTICIDES						
Aldrin	ug/kg wet wt	<1	<1	<5	<1	--
BHC, alpha-	"	<1	<1	<5	<1	--
BHC, beta-	"	<1	<1	<5	<1	--
BHC, gamma- (Lindane)	"	<1	<1	38	<1	--
BHC, delta-	"	<1	<1	<5	<1	--
Chlordane	"	<1	<1	<5	<1	--
DDT, 4,4'-	"	<1	<1	7	<1	--
DDE, 4,4'-	"	<1	<1	<5	<1	--
DDD, 4,4'-	"	<1	<1	<5	<1	--
Dieldrin	"	<1	<1	<5	<1	--
Endosulfan, alpha-	"	<1	<1	<5	<1	--
Endosulfan, beta-	"	<1	<1	<5	<1	--
Endosulfan sulfate	"	10	11	290	<1	--
Endrin	"	<1	<1	<5	<1	--
Endrin aldehyde	"	<1	<1	<5	<1	--
Heptachlor	"	<1	<1	<5	<1	--
Heptachlor epoxide	"	<1	<1	<5	<1	--
Toxaphene	"	<30	<30	<150	<30	--
Surrogate: Hexabromobenzene	Pcnt recov.	113	95	88	65	--
ORGANOPHOSPHORUS PESTICIDES						
Azinphos, methyl (Guthion)	ug/kg wet wt	<1	<1	<1	<1	--
Azinphos, ethyl	"	<1	<1	<1	<1	--
Carbophenothion	"	<1	<1	<1	<1	--
Coumaphos	"	<1	<1	<1	<1	--
DEF	"	<1	<1	<1	<1	--
Diazinon	"	<1	<1	<1	<1	--
Dichlorvos (DDVP)	"	<1	<1	<1	<1	--
Dimethoate	"	<1	<1	<1	<1	--
Dioxathion	"	<1	<1	<1	<1	--
Disulfoton (Di-Syston)	"	<1	<1	<1	<1	--
EPN	"	<1	<1	<1	<1	--
Ethion	"	<1	<1	<1	<1	--
Fenthion	"	<1	<1	<1	<1	--
Folex	"	<1	<1	<1	<1	--
Imidan	"	<1	<1	<1	<1	--
Malathion	"	<1	<1	<1	<1	--
Mevinphos	"	<1	<1	<1	<1	--
Monocrotophos	"	<1	<1	<1	<1	--
Parathion, methyl	"	<1	<1	<1	<1	--
Parathion, ethyl	"	<1	<1	<1	<1	--
Phencapton	"	<1	<1	<1	<1	--
Phorate	"	<1	<1	<1	<1	--
Ronnel	"	<1	<1	<1	<1	--
HERBICIDES						
2,4-D	ug/kg wet wt	<10	<10	<10	<10	--
2,4-DB	"	<10	<10	<10	<10	--
2,4,5-T	"	<10	<10	<10	<10	--
2,4,5-TB	"	<10	<10	<10	<10	--
2,4,5-TP (Silvex)	"	<10	<10	<10	<10	--
Bromoxynil	"	<10	<10	<10	<10	--
Dicamba	"	<10	<10	<10	<10	--
Dinoseb	"	<10	<10	<10	<10	--
Ioxynil	"	<10	<10	<10	<10	--
MCPA	"	<100	380	330	<100	--
MCPB	"	<100	<100	<100	<100	--
MCPP	"	<100	<100	<100	<100	--
Phenol, pentachloro-	"	6	4	140	1	--
Phenol, tetrachloro-	"	4	1M	6	<1	--
Picloram	"	<10	<10	<10	<10	--

B = Detected in method blank.
J = Estimated value; analytical holding times were exceeded.
M = Presence of material verified but not quantified.

Appendix H. Macroinvertebrate community structure in Whatcom Creek in July, November, and December 1987. Organism abundance is coded as: R = Rare (1-4); C = Common (5-25); and A = Abundant (greater than 25).

	DATE, METHOD, AND SITE*																																		
	7/16/87															11/24/87									12/7/87										
	5-Rock										Vegetation					Riffle Kick				Vegetation					Riffle Kick										
Taxonomic Group	0.2	0.2r	0.7	0.7r	1.1	1.1r	1.8	1.8r	2.2	2.2r	0.2	0.7	1.1	1.8	2.2	0.7	1.1	1.4R	1.8	0.7	1.1	1.4L	1.4R	1.8	0.65	0.65r	0.65t	0.71	0.74	0.75	0.75r	0.75t	0.95	0.96	1.1
Hirudinea (leeches)	R	-	-	-	-	-	-	-	-	-	R	R	-	-	-	C	-	-	-	-	-	-	-	-	R	-	-	R	-	R	-	-	-	-	-
Oligochaeta (worms)	-	R	C	A	-	R	-	-	-	-	R	-	-	-	-	R	-	-	R	-	-	-	-	-	R	R	R	R	R	-	-	R	-	R	R
Amphipoda (amphipods)																																			
Gammaridae	C	C	C	C	C	R	C	R	R	C	R	C	C	-	C	A	R	C	C	R	-	R	R	A	C	-	R	C	R	R	R	C	R	C	C
Hydracarina (mites)	C	C	A	C	C	C	R	-	-	-	-	R	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R
Plecoptera (stoneflies)																																			
Nemouridae	-	-	-	-	-	-	R	R	R	-	-	-	-	-	C	-	R	-	C	-	-	-	-	-	R	-	-	-	R	-	-	-	C	R	R
Perlidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	R
Perlodidae	-	-	R	-	R	R	R	R	R	R	-	-	-	-	-	C	C	R	R	-	R	R	-	-	R	-	R	R	-	-	-	-	R	R	R
Ephemeroptera (mayflies)																																			
Baetidae	-	-	-	A	C	-	A	C	A	C	C	C	R	R	C	-	A	A	A	-	R	-	R	C	-	-	-	C	R	-	R	R	R	C	C
Ephemerellidae	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Heptageniidae	-	-	-	-	A	C	C	C	A	C	-	-	-	-	-	R	C	R	C	-	-	-	-	-	-	-	-	-	-	R	-	-	R	R	R
Leptophlebiidae	-	-	-	-	-	-	R	R	-	-	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trichoptera (caddisflies)																																			
Glossosomatidae	R	C	A	A	C	C	R	R	C	C	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	R	C	-	C	R	C	-	-	-	-
Hydropsychidae	-	R	-	R	-	-	-	R	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hydroptilidae	-	-	-	C	R	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidostomatidae	R	R	-	-	-	-	-	-	-	-	C	R	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Limnephilidae	R	R	R	-	-	-	-	R	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Philopotamidae	-	-	-	-	-	-	R	-	R	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polycentropodidae	R	-	-	-	-	-	-	-	-	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhyacophilidae	R	-	R	R	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	-	-	-
Unidentified forms **	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	C	R	R	-	-	-	R	R	-
Anisoptera (dragonflies)																																			
Aeshnidae	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Libellulidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zygoptera (damselflies)																																			
Coenagrionidae	-	-	-	-	-	-	-	-	-	-	C	C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified forms **	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	-
Coleoptera (beetles)																																			
Dytiscidae	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Elmidae	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Haliplidae	R	-	R	R	-	-	-	-	-	-	-	-	R	-	-	R	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Unidentified forms **	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	-	-	-	R	R	-	R	-	-
Megaloptera (alderflies)																																			
Sialidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	R	R	-	-	-	-	-	R	-
Diptera (true flies)																																			
Chironomidae	C	C	A	C	C	C	R	R	R	-	C	R	C	-	C	A	R	C	C	-	C	R	R	C	R	-	-	R	-	-	-	-	C	R	C
Dixidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-
Empididae	-	-	R	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhagionidae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-
Simuliidae	-	-	-	-	-	-	-	R	R	R	-	-	R	C	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tipulidae	R	R	C	C	R	R	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-	-	-	-	R	R	-	-	-	R	R	C	-	R
Gastropoda (snails)																																			
Ancylidae	-	R	R	C	A	A	-	-	-	R	R	R	-	-	-	-	R	R	R	-	-	-	-	R	-	R	-	-	R	R	R	-	R	-	-
Lymnaeidae	-	R	R	R	-	-	-	-	-	-	C	C	-	-	-	C	-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-	-	-	-
Physidae	R	R	R	R	-	-	-	-	-	-	C	C	-	-	-	C	-	R	-	-	-	R	-	-	C	C	R	C	-	R	-	-	-	-	-
Planorbidae	R	C	C	R	-	-	R	-	-	-	C	-	-	-	-	A	-	-	-	-	-	R	-	-	R	R	R	C	C	-	R	-	R	-	-

*Numeral = river mile; r = replicate sample; t = triplicate sample; R and L = sampling biased to right (R) or left (L) bank (facing downstream). Locations of invertebrate sampling sites were same as water quality sites, with the following new sites: 0.65 = Old BNRR bridge; 0.71 = mainstem site 0.7; 0.74 = just upstream of storm drain located 20 m NW of State St bridge; 0.75 = between storm drain under State St bridge and storm drain on E side of Ellis St bridge; 0.95/0.96 = just below/above Meador Avenue bridge; 1.4 = just above Lincoln Creek confluence.

**Families were not identified due to field constraints.

Appendix I. Qualitative assessment of invertebrate habitat quality in Whatcom Creek on July 16, 1987.

Parameter	Site 0.2	0.7	1.1	1.8	2.2
Time	1000	1200	1400	1540	1650
Mean Width (ft)	30	20	30	30	30
Mean Depth (ft)					
Riffles/Runs	1	1	0.7	0.7	1
Pools	5	2.5	4	2	5
Substrate Composition *					
Fines (<1/4")	R	C	C	R	R
Gravel (1/4"-3")	R	C	A	C	R
Cobble (3"-12")	R	A	C	A	A
Boulder (>12")	N	C	R	R	C
Bedrock	A	N	N	N	N
Detritus	N	N	N	N	N
Clay	R	N	R	N	N
Canopy Cover (Shading) *	A	C	R	A	A
Bank Stability **	G	G	G	G-E	F-G
Bank Vegetation *	A	C	C	C	C
Aquatic Plants *					
Slimes	N	N	N	N	N
Periphyton	A	A	C	N-R	C
Filamentous Algae	R	N	N	N	N
Macrophytes	R	R	A	N	N
Aesthetics **	G	P-F	P-F	E	E
Predominant Land Use ***	C-P	C	C	C-F	F

* N = None (0%)
R = Rare (<10%)
C = Common (10-50%)
A = Abundant (>50%)

** P = Poor
F = Fair
G = Good
E = Excellent

*** C = Commercial
F = Forested
P = Park corridor